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S103 discovering science

Note that the times shown in the study plan overleaf do not include the time that you will need to answer questions on the DVD and the TMA, making use of the set book, attending sessions at your local or regional centre or reflecting on what you have learned and how you have learned it. Past students have also commented that *our* estimates of the times needed for the study of the DVD-multimedia activities are likely to be low.

Study Guide for Block 6

The theme of the first half of *Discovering Science* is 'taking the world apart', and this block makes a more than generous contribution to it. For example, it shows how substances that you can see with the naked eye, like the minerals that you met in Block 3, are composed of tiny invisible atoms. But the process doesn't stop there. By the time the block has finished, the atoms have themselves been taken apart into bits and pieces called protons, neutrons and electrons. At the same time, the arguments that are used are designed to reveal science as a process of discovery. To achieve this, scientific experiments must take a very prominent place, and this emphasis is a feature that marks this block out from its predecessors.

The experimental background to the arguments is extremely important: the three DVD-video activities demonstrate experiments, and there is some optional practical work. Look now at the list of equipment and materials in the Study File notes for Activity 13.2, so that you are prepared when the time comes.

The main DVD-multimedia activity is about the Periodic Table, and it comes in two parts: 'Chemical periodicity' and 'Surveying the Periodic Table'. Both parts should be done at the end of Section 12, but their structure offers you the chance to take a break between the two parts, or between sections in 'Chemical periodicity'. The study plan overleaf shows that 3 hours have been allocated to this activity, even though the introductory screens will suggest that 2 hours is adequate. The extra hour enables you to revisit sections, and to reflect upon them. There is also an optional DVD-multimedia activity on the balancing of chemical equations, which provides valuable practice in this important topic. It is best studied after Section 11.

At intervals in the text, material appears in boxes. Their purpose is to provide background and contexts that will make the substances and concepts more interesting. You can, however, give this material a lower priority than other text, and just skim-read the boxes. Much more important are the summaries of the main ideas, which appear at regular intervals. These are quite extensive, and often contain all or nearly all of what you will need to know when you do the questions that immediately follow. You will find that Sections 3–10 contain quite a lot of arithmetic. This is straightforward, but you will need to keep your calculator by you to perform the calculations.

The study plan overleaf shows roughly how you should divide your time during the three study weeks allocated to Block 6. You will also need to allocate time for the assignments, for meetings at your local study centre, and for the DVD questions that cover this block. The DVD questions on chemical periodicity are particularly important, because there are relatively few questions on this subject in the book.

Block 6 is assessed in TMA 05.

One word of warning before you start reading: Sections 1 and 2 describe experiments in which we make some of the substances that will provide us with reasons for believing in the atomic theory. If such experiments are unfamiliar, the experience will be rather like that of taking up cooking. Things can seem bewildering to start with, because the ingredients have unusual names, and so do the implements. We have tried to keep this terminology under control, but ultimately, some of it has to be learnt. If the various pieces of apparatus seem unfamiliar, the diagrams and photographs in the text, and, later, the DVD-video activities, should help you to get used to them. The names of the substances may present greater difficulties. At this stage, think of such a name as just a label for a particular substance with its characteristic properties. Thus, just as parsley describes the leaves of a plant with a particular fragrance, so sodium chloride describes a substance that consists of white solid crystals that have, among other things, a salty flavour, and dissolve in water. Later, you will see that such names have a certain rationale, which makes them easier to learn. So do not be alarmed if there seems to be a lot of new equipment and new substances in the early part of Block 6. They will soon become familiar as they are used repeatedly throughout the block.

You should begin your study of Block 6 by reading Section 1 of the book.

4.1 DS

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6 Our world and its atoms

All study times are in hours

Week	Sections of Book 6	Total study time	DVD-multimedia, DVD-video and practical activities
1	1 Introduction		
1	2 Doing chemistry	$2\frac{1}{2}$	video $\frac{1}{2}$
1	3 Doing chemistry quantitatively	$1\frac{1}{2}$	
1	4 Elements and compounds	$1\frac{1}{4}$	
1	5 The oxides of carbon	1	
1	6 An atomic theory	$2\frac{1}{2}$	video $\frac{1}{2}$
2	7 Getting to know gases	$3\frac{1}{2}$	
2	8 The Italian job	$2\frac{1}{2}$	
2	9 Revisiting equation-balancing	$\frac{1}{2}$	
2	10 Relative atomic masses	$3\frac{1}{2}$	
2	11 A second look at acids	1	
3	12 Chemical periodicity	4	multimedia 3
3	13 Atoms and electrons	$2\frac{1}{2}$	video $\frac{1}{2}$
3	14 Taking the atom apart	$3\frac{1}{2}$	
3	15 Final thoughts	$\frac{1}{4}$	

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S103 discovering science

Study File for Block 6

Contents

Notes on activities

You should read through the notes for each activity before attempting it. After completing an activity you should study the relevant comments in the next section of the Study File.

No estimate of time is given for activities that should take 10 minutes or less.

Activity 2.1 Introducing chemistry

video

(*The estimated time for this activity is 30 minutes.*)

There is a series of four DVD-video sequences associated with this block. The series is entitled 'Atoms', and the first sequence, which you will watch in this activity, is called 'Introducing chemistry'. The chemical reactions that you will see in it are all described in Section 2 but, by watching them as well as reading about them, you will get a much clearer impression of how chemical reactions are carried out.

'Introducing chemistry' is on DVD 1 (DVD-video sequence 332–416). You should view this now.

Activity 2.2 A glossary of chemicals

A good way of consolidating your feel for the chemical substances in Block 6 is to compile your own glossary of them, in much the same way that you compiled a glossary of biological terms in Block 4 and a glossary of algebraic symbols and equations in Block 5. We suggest that you restrict yourself to the more important substances, and these are the ones that the text tells you a bit about, or that are mentioned several times. At this stage, suitable candidates are sulfuric acid, nitric acid, hydrochloric acid, hydrogen chloride, sodium chloride, sodium nitrate, magnesium, hydrogen, calcium carbonate, carbon dioxide and calcium chloride. Your glossary could take the form of a table, like Table 2.2.1, or you may prefer to use another system, such as filing cards or loose-leaf sheets, as discussed in Block 4 Activity 2.2.

4.1 DS

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Table 2.2.1 Possible tabular form of a glossary of chemical substances in Block 6.

Substance	Properties	Experimental uses and theoretical contribution in Block 6	Chemical formula
sulfuric acid	colourless, dense, corrosive, oily liquid	preparation of nitric acid and hydrogen chloride; drying agent for gases and in desiccators; used to develop concept of acids	

The table shows a possible entry for sulfuric acid at this stage of the block. As you proceed, you can add other substances, and more information to the entries that are already there. For example, after Sections 6.3 and 8.3, you will be able to add some chemical formulae to the last column. So make sure that you leave space both for these formulae and for additional substances.

At the end of Section 6

This is a good time to add new substances that you've met in Sections 3–6 to your glossary. Suitable candidates can be found in the reaction flow diagrams of Figures 4.3 and 6.9: copper, oxygen, copper oxide, water, calcium oxide (quicklime), sodium hydroxide (caustic soda), soda lime, sugar, carbon, carbon monoxide and methane. You may also wish to add more information to the entries from Section 2, particularly the acids.

At the end of Section 13

This is a good time to complete your glossary of chemical substances. Suitable candidates to add from the DVD-video sequence are calcium hydroxide, ammonium chloride, ammonia, potassium hydroxide and chlorine. From Activity 12.1, you can add entire families of chemical elements, such as the alkali metals, the noble gases and the halogens. You can also put in classes of substances, such as metals, acids or salts, along with some examples and some typical properties and reactions of each. It is useful to group similar substances together into such classes or categories; with so many different substances to study, noting properties, trends and patterns within a class should help your understanding and learning.

Activity 4.1 The chemical composition of hydrogen chloride

(*The estimated time for this activity is 15 minutes.*)

In this activity you will consider the design of an experiment to determine the chemical composition of hydrogen chloride, and calculate its composition from experimental results.

How have you determined the chemical composition of substances so far?

By finding out the masses of elements that combine to give a known mass of compound (Questions 4.1 and 4.2).

But it is quite difficult to determine the masses of hydrogen and chlorine that combine to form hydrogen chloride, because all three substances are gases. So instead, we shall take hydrogen chloride apart into its constituent elements. We shall start with a known mass of hydrogen chloride and remove the chlorine from it by a reaction you met in Section 3.1: it is converted into solid white particles of silver chloride, by adding sufficient silver nitrate solution. The precipitate of silver chloride that is formed can be filtered off, dried and weighed.

If you know the mass of silver chloride, how can you work out the mass of chlorine?

You can calculate it from the chemical composition of silver chloride (which you determined in Question 4.2).

Task 1 Thinking about the practical procedure

Your first job is to obtain a known mass of hydrogen chloride which you can subsequently take apart. As you saw in Activity 2.1, hydrogen chloride dissolves very easily in water, so a good way of doing this is to pass the gas into water, and measure the increase in mass. Figure 4.1.1 shows a suitable apparatus. Outline a way of using it to

obtain a solution containing a known mass of hydrogen chloride. Then describe how you would use silver nitrate solution to convert the chlorine in that hydrogen chloride into silver chloride.

Check your answer with the comments on this task, before moving on.

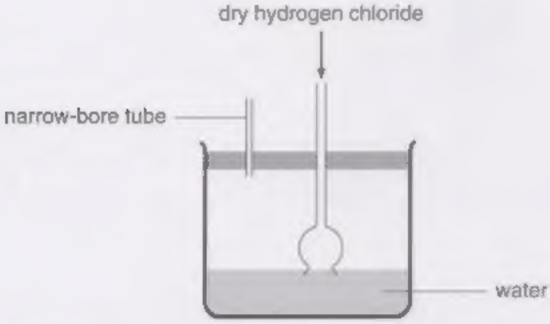

Figure 4.1.1 Apparatus for making a solution of hydrogen chloride in water.

Task 2 Thinking about the experimental design

Here are some things to think about in relation to Figure 4.1.1 and the detailed instructions given in the comments on Task 1. Jot down your answers, then check them with the comments.

(a) Why is a tube with a narrow bore inserted into the bung?

(b) Why is an inverted thistle funnel (so-called because of its shape) used, rather than just a straight tube as in Figure 2.6? (*Hint*: referring to Figure 2.14 may help.)

(c) Why is it necessary to rinse the inlet tube and to collect the washings in the beaker?

(d) Why is silver nitrate added until no more precipitate is formed?

(e) Why is the silver chloride dried before it is weighed?

Task 3 Calculating the percentage composition of hydrogen chloride

In a particular experiment, the mass of hydrogen chloride dissolved in the water was 1.000 g, and the mass of silver chloride precipitated from the hydrogen chloride solution was 3.937 g.

(a) In Question 4.2 you found that silver chloride contained 24.7% chlorine. Use this result to calculate the mass of chlorine in the 3.937 g of silver chloride precipitated in this experiment.

$\frac{24.7}{100} \times 3.937 = 0.972g$

(b) Use the answer to part (a) to calculate the percentage composition of hydrogen chloride.

97.2% chlorine 2.8% hydrogen

(c) Use your answer to part (b) to calculate the mass of chlorine that is combined with 1.00 g of hydrogen in hydrogen chloride.

$\frac{97.2g}{2.8} = 35g$

Activity 6.1 An exercise in experimental design

(*The estimated time for this activity is 20 minutes.*)

(a) The composition of methane can be found by weighing the products of the following reaction:

methane + copper oxide ⟶ carbon dioxide + water + copper

Sketch an apparatus that would allow you to collect and weigh the products of this reaction. Your sketch should be a combination of the components that are drawn and listed in Figure 6.1.1, and should include the chemicals calcium chloride, copper oxide and soda lime in their proper places. Remember that soda lime has some water-absorbing tendencies.

You will find an explanation, and a suitable design for the proposed experiment in the comments on this activity. Check your suggestions against these items before doing part (b) of this activity.

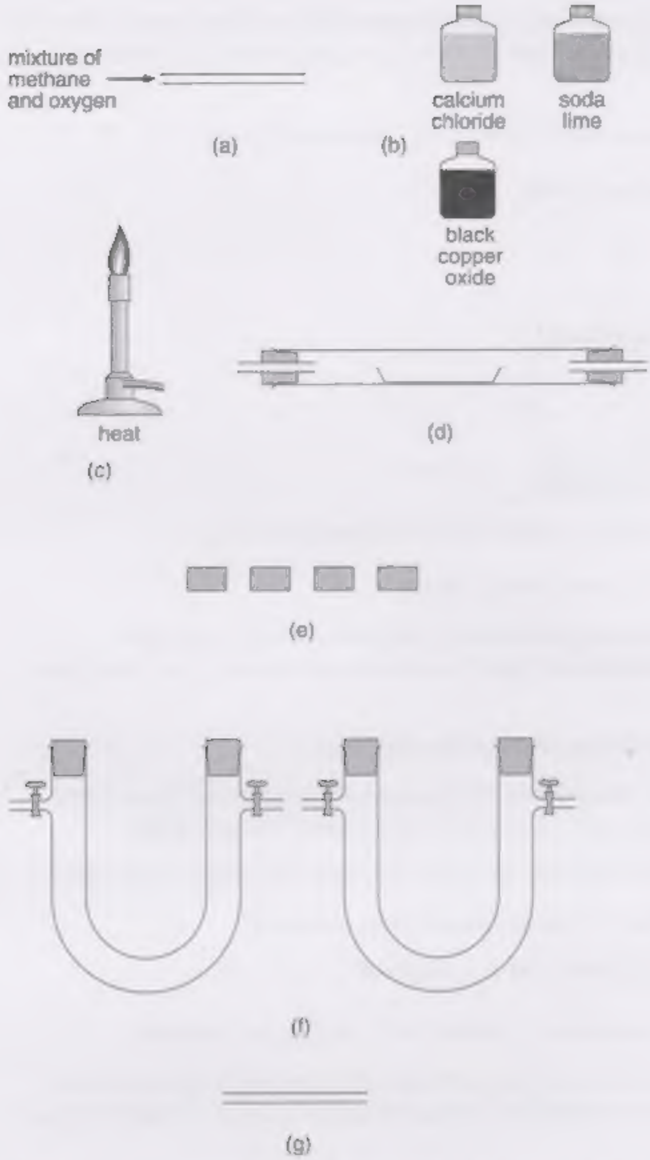

Figure 6.1.1 The chemistry set that you need for determining the composition of methane. It consists of: (a) a tube delivering a mixture of dry methane and oxygen; (b) bottles of copper oxide, soda lime and calcium chloride; (c) heat source; (d) a long large-diameter glass tube containing a long porcelain boat and bearing stoppers with delivery tubes at each end; (e) four short bits of polythene tubing for connecting glass tubes; (f) two U-tubes with taps that can seal or open the U-tube contents to a gas stream; (g) a glass tube for carrying away waste gases.

(b) In one particular experiment, the mass of the calcium chloride tube increased by 0.500 0 g. At the same time, the mass of the soda lime tube increased by 0.611 7 g. Use these figures, together with the fact that water contains 11.2% hydrogen (Section 3.5), and carbon dioxide contains 27.3% carbon, to calculate the percentages of carbon and hydrogen in methane.

(c) You have done a number of questions and activities that required you to calculate percentage compositions of chemical compounds, and you will meet other examples later in this block. You should make sure that you can calculate the masses of the component elements from the percentage composition of a compound and vice versa. To reinforce these procedures, look at your response to part (b) and note down, with an example, the general procedure that you use:

(i) to calculate the mass of an element in a certain mass of a compound when you know the percentage composition, and

(ii) to calculate the percentage composition of a compound when you know the masses of the component elements.

Activity 6.2 Elements, compounds and the atomic theory

(*The estimated time for this activity is 30 minutes.*)

In this activity you will watch the second and third of the four DVD-video sequences associated with this block. These sequences are entitled 'Elements and compounds' and 'The atomic theory'. The chemical reactions that you will see in them are all described in Sections 3–6, and watching them will help you to appreciate how these reactions take place, as well as reinforcing your understanding of the discussion in the book.

'Elements and compounds' and 'The atomic theory' are on DVD 1 (DVD-video sequences 417–464 and 465–509). You should view these now.

Activity 6.3 Using the scientific method: reviewing the argument in Sections 3–6

(*The estimated time for this activity is 20 minutes.*)

Scientists commonly gather evidence, think about it and develop a hypothesis to explain what they have observed. Sections 3–6 have presented the 'story' in this way, gathering evidence from experiments and using this evidence to propose that an element is composed of atoms, each of identical mass, and that compounds are composed of the atoms of different elements combined in simple numerical ratios. These propositions form the basis of what is now known as the *atomic theory*.

(a) Below, you will find three items of experimental evidence, (i)–(iii), which we have used to develop the atomic theory. They appear in the order in which they were used in Sections 3–6. There are also seven statements A–G. For each item (i)–(iii) identify one statement (A–G) that the item was used to justify.

Items of evidence

(i) When silver nitrate solution and dilute hydrochloric acid in a sealed container are mixed, silver chloride is formed, but the mass of the container and its contents does not change.

(ii) Whether black copper oxide is made by heating copper with oxygen, or by dissolving copper in nitric acid and strongly heating the product, every 1.252 g of copper oxide contains 1.000 g of copper.

(iii) Water can be taken apart into hydrogen and oxygen by passing an electric current through it; it can then be recovered by burning hydrogen in oxygen when the hydrogen and oxygen combine.

Statements

A Every carbon atom is combined with one oxygen atom in carbon monoxide (CO).

B A chemical substance with its distinctive properties — colour, melting temperature, chemical reactions — has a fixed, characteristic chemical composition.

C Chemical elements are composed of atoms.

D We cannot get chemical formulae unless we know relative atomic masses.

E Three oxygen atoms have the same mass as four carbon atoms.

F During any chemical reaction, there is no detectable change in mass.

G Some substances can be broken down into simpler constituents; these are called chemical compounds. Others cannot; these are called elements.

(b) In Table 6.3.1, a fourth item of experimental evidence appears, along with an interpretation of it that involves the atomic theory. In this interpretation, there are missing steps that are marked by the numbers 1, 2, 3 and 4. Complete the explanation by replacing each number with one of the statements A–G not used in (a).

Table 6.3.1 For use in Activity 6.3b.

Experimental evidence	Interpretation
When 3.0 g of carbon forms carbon dioxide, it combines with 8.0 g of oxygen; when it forms carbon monoxide, it combines with 4.0 g of oxygen. These two masses of oxygen are in the exact ratio 2 : 1.	Suppose that (1), that all the atoms of a particular element are identical, especially in mass, that atoms of carbon have a different mass from atoms of oxygen, and that chemical combination occurs by the union of the atoms of the elements in simple whole number ratios.
	It follows that *if* (2), then every carbon atom must be combined with two oxygen atoms in carbon dioxide (CO_2), and (3).
	But we do not *know* that carbon monoxide is CO. So we have a dilemma. We cannot get relative atomic masses unless we know chemical formulae, and (4).

(c) The evidence that we have used so far to justify the atomic theory has leaned very heavily upon the oxides of carbon. But once a theory or hypothesis has been proposed, scientists test it out by looking for other instances that might corroborate it. In Question 6.1, you obtained results that show that 0.252 g of oxygen are combined with 1.000 g of copper in black copper oxide, and with 2.000 g of copper in red copper oxide. Write this experimental evidence into the first column of a table like Table 6.3.1. Assuming that black copper oxide has the chemical formula CuO, insert into the second column a rewritten version of the second column of Table 6.3.1 that refers to copper and its oxides rather than to carbon and its oxides. This rewritten table should then provide further support for the atomic theory.

Activity 6.4 Using the scientific method: combining sources of evidence to formulate an opinion

(The estimated time for this activity is 15 minutes.)

In this activity you will play the part of a forensic scientist in a hypothetical incident. You will need to gather evidence from a brief account of an event, to combine this evidence with scientific knowledge that you have acquired while studying this block, and then to make a judgement. Here is the account:

> Because they had visitors, a university laboratory technician and his wife slept in a caravan outside their home. The caravan was heated by a gas fire. When another member of the family went out in the morning, he saw the husband fall unconscious through the half-opened door of the caravan. Inside, the wife lay dead in her bed. Laboratory tests showed that 85% of the haemoglobin in the wife's blood had been converted into carboxyhaemoglobin; for the husband, the figure was 15%.

Use the information in Box 5.1, and in Figures 5.5 and 6.4.1, to identify any puzzling features about the incident. Then explain, in about 150 words, why further investigations by the police may be justified.

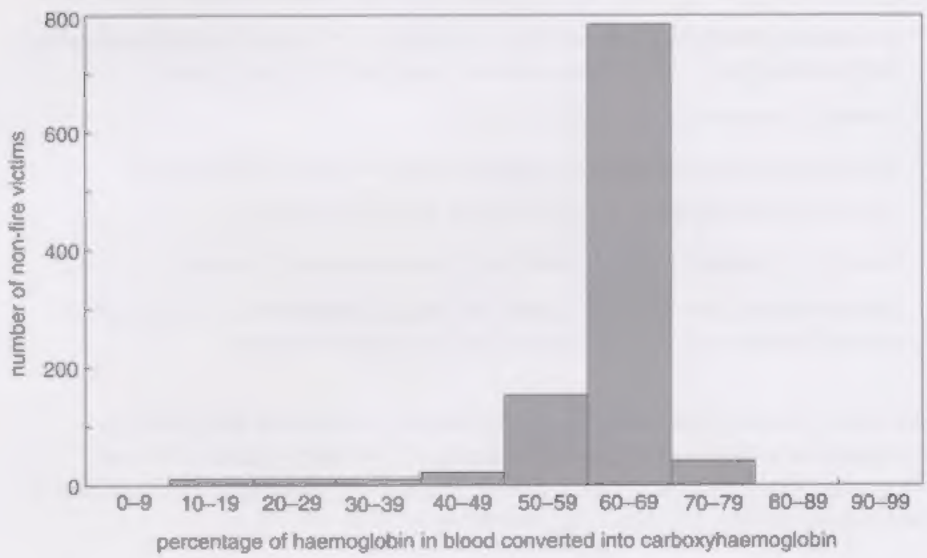

Figure 6.4.1 Histogram showing the percentage of haemoglobin converted into carboxyhaemoglobin for 1 020 non-fire deaths by carbon monoxide poisoning in the United States between 1960 and 1979. Data are from the Case Western Reserve University data bank. Most deaths occur in the range 50–70%.

Activity 6.5 Using your knowledge to write critically about somebody else's chemistry

(*The estimated time for this activity is 20 minutes.*)

An important skill that you will develop as you study *Discovering Science* is the ability to use your increasing knowledge of science to criticize the science in articles, books and broadcast programmes. This activity provides an opportunity to develop this skill.

Edgar Wallace was the most successful thriller writer of the 1920s, and a TV series was devoted to Mr J. G. Reeder, his fictional detective. In *The Stealer of Marble*, a deranged woman locks the heroine in a telephone kiosk and prepares to kill her by pouring jugs of gas through a hole in the roof. Mr Reeder intervenes just in time, and in Figure 6.5.1, he explains the plan for the intended murder (marble, like chalk and limestone, is a form of calcium carbonate).

Read the extract, highlighting parts that refer to properties of named gases and noting which are accurate and which inaccurate. Then write a paragraph of up to 200 words that criticizes Edgar Wallace's knowledge of chemistry. Your account needs to make it clear where the science in the extract is right and where it is wrong; it should also indicate where any confusion might have arisen, and finish by assessing whether the gas prepared in the way described is suitable for the job in hand.

> Mr Reeder took the inspector up to the little room and showed him its contents.
>
> 'This funnel leads to the telephone box—' he began.
>
> 'But the jugs are empty,' interrupted the officer.
>
> Mr J. G. Reeder struck a match and, waiting until it burnt freely, lowered it into the jug. Half an inch lower than the rim the light went out.
>
> 'Carbon monoxide,' he said, 'which is made by steeping marble chips in hydrochloric acid – you will find the mixture in the tank. The gas is colourless and odourless – and heavy. You can pour it out of a jug like water. She could have bought the marble, but was afraid of arousing suspicion. Billingham was killed that way. She got him to go to the telephone box, probably closed the door on him herself, and then killed him painlessly.'
>
> 'What did she do with the body?' asked the horrified officer.

Figure 6.5.1 An extract from *The Stealer of Marble* by Edgar Wallace.

Activity 7.1 Keeping hold of the argument in Sections 7 and 8

The problem that we identified at the end of Section 6 — the dilemma of not knowing either chemical formulae or relative atomic masses — will be solved in Sections 7 and 8 by comparing the *densities* of gases such as hydrogen, methane and hydrogen chloride. Some of the concepts involved are more difficult to grasp than those in Sections 1–6 and there are also several different strands to the argument. This activity starts by setting out briefly the structure of the argument and then provides you with a diagram showing this structure and with a set of questions related to the important steps. These will help you to follow the argument as you work through Sections 7 and 8.

Introduction to the structure of Sections 7 and 8

As you know from Block 1, the density of a substance is found by dividing the mass of a sample by its volume. In Block 2 Activity 6.2, a DVD-video sequence showed you how to determine the mass of a gas such as air. So to calculate its density, all we need to do is to divide that mass by the gas volume. Here, however, there is a difficulty: as you will see in Figure 7.5, the volume of a gas is sensitive to the pressure to which the gas is subject.

Gas volumes are also sensitive to temperature: a balloon tied down in iced water increases steadily in size as the water is heated. So to make a scientific comparison of gas densities, we must first devise ways of determining gas volumes at the same pressure and temperature. This is the subject of Sections 7.1–7.4. Then, in Section 7.5, the observations made in Sections 7.1–7.4 are shown to be consistent with the particle model of a gas that you met in Block 2. Next, Section 7.6 describes how gas densities are determined at a temperature of 0 °C and a pressure written as 760 mm of mercury. This is called standard temperature and pressure (STP). The resulting densities are compared in

Table 7.3. These densities are used in Sections 7.7–8.1 to develop two new scientific laws (Gay-Lussac's law and Avogadro's hypothesis). Sections 8.2–8.4 then solve the problem raised at the end of Section 6.

This structure is shown in Figure 7.1.1. We suggest that you refer to this figure, and the above explanation, as you work through Sections 7 and 8. You can strengthen your grasp of the argument by answering the questions to the right of Figure 7.1.1 as you complete the relevant section.

Section	Function	Questions
Sections 7.1–7.4	Introduces two laws that show how the volume of a gas changes when the pressure or temperature changes.	(a) Name the laws and write them out in mathematical symbols.
Section 7.5	Shows how the particle model of a gas explains the volume changes described above.	(b) Explain why the volume of a gas is decreased by an increase in pressure, but increased by an increase in temperature.
Section 7.6	Determines the volume and density of a gas at 0 °C and a pressure of 760 mm of mercury.	(c) What gas was chosen? Which of the two gas laws was used to correct the gas volume to STP? Why was only one needed?
Table 7.3	Compares densities of different gases at STP.	(d) Name the least and most dense gases in the table. What applications of these two gases, related to their densities, have been mentioned in the block?
Sections 7.7–8.1	Uses these gas densities to introduce two new laws of gas behaviour.	(e) Name the laws. What do they lead you to conclude about a litre of hydrogen and a litre of oxygen at the same temperature and pressure?
Sections 8.2–8.4	Solves the problem identified in Section 6.5.	(f) State the new principle that is essential to the solution. What does it add to what the previous question told us about the litre samples of hydrogen and oxygen?

Figure 7.1.1 The structure and function of Sections 7 and 8.

Activity 7.2 Combining Boyle's and Charles' laws

(The estimated time for this activity is 15 minutes.)

Boyle's law allows us to calculate how the volume changes when the pressure changes (assuming that the temperature is fixed), and Charles' law allows us to calculate how the volume changes when the temperature changes (assuming that the pressure is fixed). When both pressure and temperature change, then the two laws need to be applied sequentially, and you will need to do this in the problem that follows. It doesn't matter in which order you apply the two laws, as you will be able to confirm by trying both options. Here is the problem you will solve.

> When a sample of hydrogen is held at a pressure of 760 mm of mercury and a temperature of 27 °C, the volume of the gas is 600 cm^3. If the pressure is increased from 760 to 1 140 mm of mercury, and the temperature to 327 °C, what will be the final volume of the sample?

(a) Use Boyle's law to calculate the volume of the gas if its temperature is kept at 27 °C while its pressure is increased from 760 to 1 140 mm of mercury. Then use Charles' law to calculate how this new volume changes when the pressure is held at 1 140 mm of mercury and the temperature is increased to 327 °C.

(b) Now use Charles' law first and calculate the volume of the gas if its pressure is kept at 760 mm of mercury, and its temperature is increased from 27 °C to 327 °C. Then use Boyle's law to calculate how this new volume changes when the temperature is kept at 327 °C and the pressure is increased from 760 mm to 1 140 mm of mercury. Does this give the same value of the final volume as in part (a)?

(c) These sorts of calculation, which involve applying Boyle's law and or Charles' law, recur quite frequently in chemistry. So to reinforce your understanding of them, look at your response to part (a) and note down how you used the two laws.

Activity 8.1 Deducing the different consequences of competing hypotheses

You saw (Figure 7.19) that under the same conditions of temperature and pressure, a particular volume of chlorine combines with *the same* volume of hydrogen when the two gases react and form hydrogen chloride. Our atomic theory implies that the numbers of molecules of chlorine and hydrogen that react will be in a simple ratio. On the left of Figure 8.1.1 you will find three statements that give possible values of this ratio, and you can think of these as being three competing hypotheses. In the centre we give, for each hypothesis, identically sized boxes for hydrogen and chlorine which represent the equal reaction volumes. Let's imagine that, as shown, there are 10 billion molecules in the chlorine box. The hydrogen box contains no entry. However, each of the three statements to the left requires a particular number of hydrogen molecules in the corresponding hydrogen box. Pencil the appropriate numbers in the hydrogen boxes, and then complete the three sentences at the right of Figure 8.1.1 by writing in, for example, 'the same as', 'ten times', 'one-eighth', as appropriate. These statements then represent the logical consequences of the three competing hypotheses

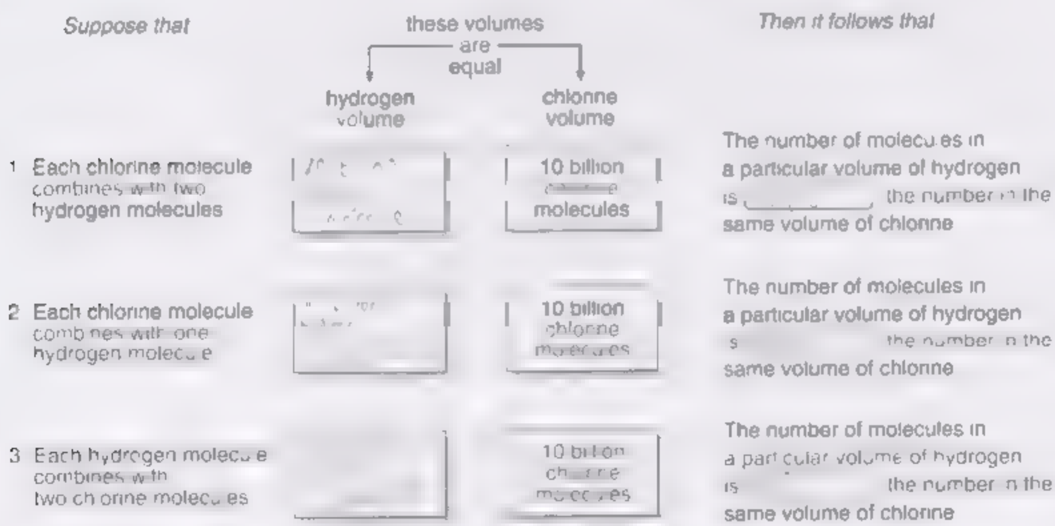

Figure 8.1.1 Hypotheses related to the reaction between hydrogen and chlorine, for use with Activity 8.1.

Activity 8.2 Counting carbon atoms

(*The estimated time for this activity is 15 minutes.*)

The procedure that was used in Section 8.3 to calculate the number of hydrogen atoms in various hydrogen compounds is quite general. It can be used to work out the number of atoms of any element in a set of that element's gaseous compounds. In this activity you will first identify the main steps in the procedure, and then apply it to a set of compounds that all contain carbon atoms.

(a) Look back through Section 8.3 and list the main steps that were used to determine the number of hydrogen atoms in each of the compounds in Table 8.1. Then rewrite the list of steps in general terms, so that it can be used for any element, not specifically for hydrogen.

Compare your list with the one in the comments before you tackle part (b).

(b) Now use this list of steps to work out the number of carbon atoms in each of the molecules in Table 8.2.1.

(c) Combine the results from (b) with the results in Table 8.1 to write down chemical formulae for methane, ethane and propane.

Table 8.2.1 Data for calculating the number of carbon atoms in the molecules of some gases

Gas	Density at STP/g litre^{-1}	Mass of molecule/g	Percentage of carbon by mass/%	Mass of carbon per molecule/g	Number of carbon atoms in molecule
methane	0.716	$\frac{[illegible]}{N}$	74.9	$\frac{0.536}{N}$	1
carbon monoxide	1.25	$\frac{[illegible]}{N}$	42 9		
ethane	1.34	$\frac{1.34}{N}$	79.9	$\frac{1.07}{N}$	2 C_2
carbon dioxide	1.96	$\frac{1.96}{N}$	27.3	[illegible]	
propane	1.97	$\frac{1.97}{N}$	81.7	$\frac{1.609}{N}$	3 C_3

Activity 8.3 Counting oxygen atoms

Use the general procedure that you wrote down in Activity 8.2a to find the number of oxygen atoms in a molecule of each of the various gases listed in Table 8 3.1.

Table 8.3.1 Data for calculating the number of oxygen atoms in the molecules of some gases.

Gas	Density at STP/g litre^{-1}	Mass of molecule/g	Percentage of oxygen by mass/%	Mass of oxygen per molecule g	Number of oxygen atoms in molecule
oxygen	1.43		100		
water vapour	0.804		88 8		
carbon monoxide	1.25		57.1		
carbon dioxide	1 96		72 7		
ozone	2.14		100		
sulfur dioxide	2.86		49 9		

Activity 10.1 Finding the molecular formula of arsine

(*The estimated time for this activity is 30 minutes*)

This activity is concerned with the gas arsine, whose properties provide the classical method of detecting arsenical poisoning (see Box 10.1.1, *Arsenic: the classical poisoner's choice*). It covers many of the important ideas of the atomic theory in Sections 3–10, and it will help you to consolidate your understanding of the important concepts that have been introduced. Because it brings so many ideas together, relevant section numbers are listed for most of the parts of the activity If you get stuck, start doing Activity 10.2 in parallel with this activity, and you will get some helpful hints.

If pure arsine is passed over a heated boat containing copper oxide (Figure 10.1.1), the following reaction occurs:

arsine + copper oxide ⟶ copper arsenide + water

The arsine's arsenic stays in the boat as solid copper arsenide; its hydrogen passes on in the gas stream as water vapour and is collected in a tube of calcium chloride. In a quantitative experiment, the following results were obtained:

initial mass of the boat and contents = 22.368 g

final mass of the boat and contents = 23.729 g

initial mass of the calcium chloride tube = 20 837 g

final mass of the calcium chloride tube = 21.558 g

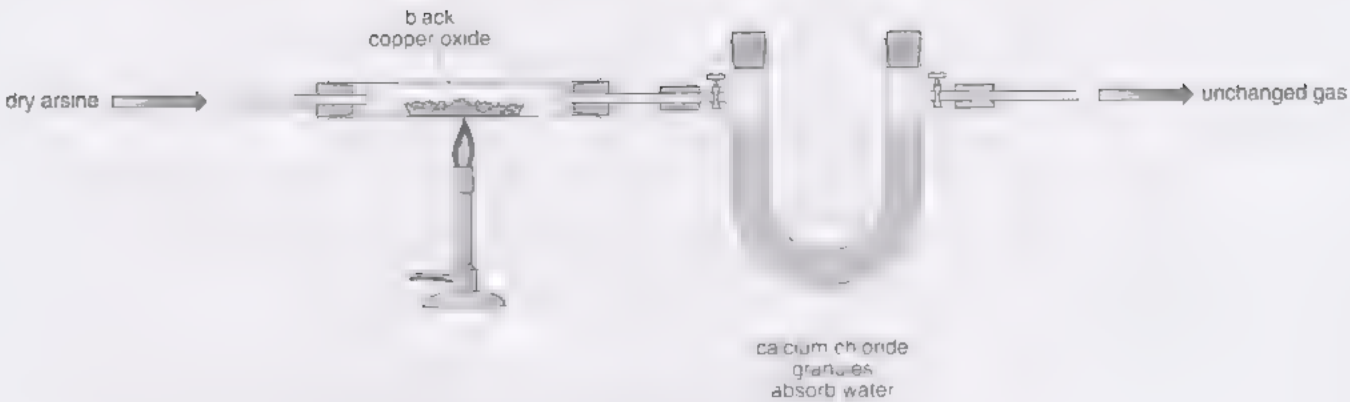

Figure 10.1.1 An experiment to determine the chemical composition of arsine.

Box 10.1.1 Arsenic: the classical poisoner's choice

When John Bodle murdered his granddad in 1833, they called in James Marsh, a penniless chemist from Woolwich Arsenal, to investigate. Marsh found arsenic in the old man's stomach and coffee cup, but his chemistry didn't convince a partisan jury, and Bodle got off (see Figure 10.8 in Block 6). So Marsh set out to find a test that would satisfy even the highest standards of proof. What he came up with featured in all the classic murder trials for arsenical poisoning of the Victorian and early 20th century periods. Recent TV documentaries have covered the cases of Florence Maybrick (1889) and Herbert Armstrong (1923).

To detect arsenical poisoning, Marsh used the most toxic of arsenic compounds. This is arsine, or arsenic hydride. It is a colourless gas with a garlic smell, and it burns with a lilac flame. While making it in 1812, the German pharmacist, Adolf Gehlen, sniffed the outside of his glassware to detect a leaky joint: he found the leak but died 9 days later after much suffering. Arsine is a powerful blood poison: a disintegration of the red blood corpuscles sets free the haemoglobin and is followed by acute kidney failure.

Marsh's test depends upon two facts: firstly, in the presence of metallic zinc and an acid, arsenic compounds form arsine; secondly, when heated, arsine decomposes into hydrogen and a dark shiny film or 'mirror' of solid arsenic. It is this deposit that reveals the presence of arsenic in the sample (Figure 10.1.2)

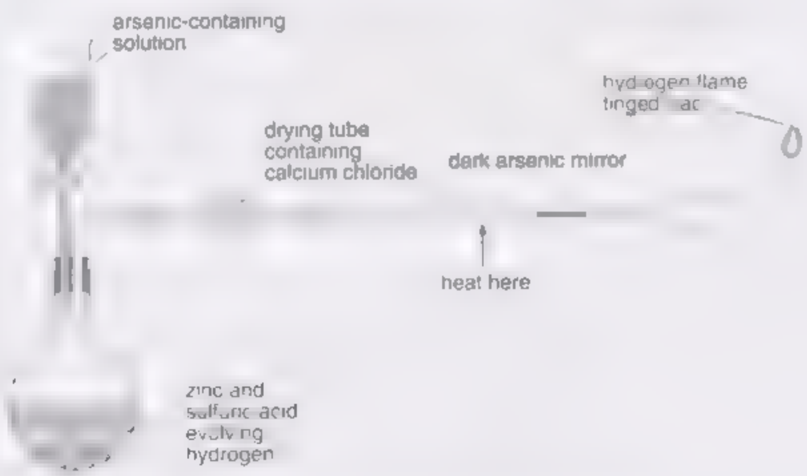

Figure 10.1.2 A version of Marsh's test: the flask contains zinc and dilute sulfuric acid from which rises hydrogen (Section 2.4.3). The gas is dried by calcium chloride and lit at the jet. A solution from, say, the stomach or kidneys of an exhumed corpse is dropped from the funnel. If that solution contains arsenic, then when the glass tube is heated, decomposing arsine forms a dark mirror of solid arsenic downstream of the heated section

(a) What mass of water vapour was formed? (Section 3.5)

(b) In Section 3.5, we found that water was 11.2% hydrogen and 88.8% oxygen. Use these data to calculate the masses of hydrogen and oxygen in the mass of water vapour that you obtained in part (a). (Sections 3.5 and 4)

(c) Two things contribute to the change in the mass of the boat. It gains the arsenic from the decomposed arsine, but it loses oxygen from the copper oxide as water vapour. Use this information, the change in the mass of the boat, and your mass of oxygen from part (b), to calculate the mass of arsenic in the arsine that decomposed. (Section 6.5 and Activity 6.1)

(d) What mass of hydrogen was contained in the arsine that decomposed?

(e) Use your answers to parts (c) and (d) to find the percentage chemical composition of arsine. (Section 3.5)

(f) Use the relative atomic masses of arsenic (74.9) and hydrogen (1.01) to find the empirical formula of arsine. (Section 10.5)

(g) The density of arsine at STP is 3.50 g litre^{-1}. That of hydrogen is 0.089 9 g litre^{-1}. What is the molecular formula of arsine? (Section 10.6)

(h) What is the valency of arsenic in arsine? (Section 10.7)

(i) In Marsh's test (Figure 10.1.2), arsine is heated and decomposes into solid arsenic and hydrogen gas. Write a balanced chemical equation for this decomposition. (Sections 9–9.2)

(j) This decomposition can also be carried out with electrical sparks if we apply a high voltage between two wires in arsine gas while it is confined over mercury. If the final temperature and pressure are the same as they were at the beginning of the sparking, and the initial volume of arsine is 10 cm^3, what volume of gas remains when the experiment is over, and of what does that gas consist? (Sections 7.8–8.1.1)

Activity 10.2 Reviewing important ideas from Sections 3–10

(*The estimated time for this activity is 15 minutes.*)

This activity can be done either after you have completed, or while you are doing, steps (a)–(j) of Activity 10.1. Below, you will find a list of nine important facts or principles that, at some stage, play an important part in the calculations of Activity 10.1. Identify from the list 1–9 *up to two* facts or principles that you rely on when doing each of the calculations (a)–(j). Notice that if you are combining this activity with Activity 10.1 because you are finding the calculations difficult, your survey of the list may provide hints that get you out of your difficulties.

1. In a chemical reaction, the mass of a particular chemical element (a particular type of atom) does not change.
2. An increase in the mass of a calcium chloride trap during a reaction tells you the mass of water vapour that has been produced.
3. Hydrogen gas consists of diatomic molecules.
4. The chemical composition of a chemical compound is a list of percentages, by mass, of its constituent chemical elements.
5. The valency of an element is equal to the number of atoms of hydrogen that one atom of that element will combine with
6. Avogadro's hypothesis leads to the conclusion that when gases react at a constant temperature and pressure, the ratio between the reacting volumes is the same as the ratio between the numbers of reacting molecules.
7. The ratio of the densities of two gases at STP is equal to the ratio of their relative molecular masses.
8. In a balanced chemical equation, there is the same number of each different type of atom on each side of the equation.
9. If the atoms of two elements are combined in a particular ratio in the chemical formula of a compound, then the molar masses of these atoms will be combined in that same ratio in the compound.

Activity 12.1 Chemical periodicity

(The estimated time for this activity is 2 hours for the first run through but we have allocated 3 hours because you are likely to want to visit parts more than once.)

This is an important activity because it introduces one of the most productive of all chemical ideas — chemical periodicity. You will use information about the chemical properties of the elements to build a Periodic Table, and will then see that this way of classifying the elements allows you not just to understand, but even to predict their properties. There are two parts to this activity: 'Chemical periodicity' should take about 1 hour 30 minutes; 'Surveying the table' will take about 30 minutes. Ideally they should be studied consecutively before you move on to Section 13, but you are advised to take at least one break from the computer during your study of this activity.

'Chemical periodicity' is on the Block 6 DVD. You should start this activity now.

Activity 13.1 Alkalis, acids and ions

(The estimated time for this activity is 15 minutes.)

In this activity you will watch the last of the four DVD-video sequences associated with this block. This sequence is entitled 'Alkalis, acids and ions'. The chemical reactions that you will see in this sequence are all described in the book, and watching the DVD-video sequence will reinforce your understanding of them.

'Alkalis, acids and ions' is on DVD 1 (DVD-video sequence 510–574). You should view this now.

Activity 13.2 Practical work: iron, vinegar and electrolysis

This activity is optional. It involves doing some practical chemistry using materials and equipment that are readily available. The activity consists of two experiments, and you can choose to do either or both of them. Each one should take you about 1 hour.

How do you choose which, if either, to do?

You should read through the aims for each part, the list of equipment and materials required, and the comments below.

Experiment 1 involves making up solutions and observing what happens when you mix two solutions together. This is 'traditional' laboratory chemistry, and in many ways is akin to cooking.

Experiment 2 involves the electrolysis of a variety of solutions. Setting up the equipment for this activity is rather 'fiddly', and requires a certain amount of manual dexterity, but if you can connect a cable to a 13 amp plug then you should be able to manage. It is worth persevering with this experiment because the results are very striking.

When you have decided which experiment(s) to do, read through all the instructions before you start the practical work.

Experiment 1: The chemistry of iron

Equipment

NON-KIT ITEMS

large saucepan with lid

six jam jars or glass tumblers

a tea-cup (for measuring)

a tablespoon

two teaspoons

Materials/chemicals

NON-KIT ITEMS

15 small iron/steel nails, not galvanized (about 2.5 cm, or 1 inch, in length)

colourless vinegar

washing soda crystals

hydrogen peroxide solution (about 5–10%) (available from most chemist's shops)

Aims

This practical work is designed to reinforce and provide physical demonstrations of some of the important ideas found in the book:

- that many metals dissolve in acids to give hydrogen gas and a solution of a salt of the metal;
- that solutions of salts contain ions;
- that the ions carry a particular charge and that some metals, including iron, form two or more types of ion with different charges;
- that when two different solutions containing ions are mixed, ions of opposite charge from the different solutions may be able to combine and form a solid that is insoluble. This type of precipitation reaction occurs in Figure 3.2 of Block 6.

Introduction

In Section 11.1 you saw that salts are formed when the hydrogen atoms of an acid are replaced by metal atoms. You will prepare a solution of a salt by the reaction of iron nails with vinegar, which is made by dissolving acetic acid in water. By observing the reactions of this solution of a salt, you will see that iron forms two different aqueous ions, with different colours.

The formula for acetic acid is quite complicated, and you do not need to worry about it in Block 6. Here we represent it as HAc, or 'hydrogen acetate', where Ac refers to the acetate part. In Section 13.4, an acid was defined as a substance that contains hydrogen and yields hydrogen ions when it dissolves in water.

- Write an equation for the dissolution of acetic acid, HAc, in water that explains its acidity.

- The equation is

$$HAc(aq) \longrightarrow H^+(aq) + Ac^-(aq) \qquad (13.2.1)$$

The solution of acetic acid contains aqueous hydrogen ions, and this explains its acidity.

> ***Safety precautions***
>
> In addition to the precautions given in Section 6 of the *Practical work booklet*, care is needed when handling some of the chemicals. Always remember to read any instructions on the container before using the chemicals.
>
> Washing soda may be harmful if swallowed and may irritate eyes on contact.
>
> Keep hydrogen peroxide out of your eyes.

Practical procedure

Preparing Solution A by treating iron nails with vinegar

Pour half a cupful of the vinegar into a jam jar, and add the iron nails to it. Stand the open jam jar in some water in the saucepan so that the water level is about 1 cm higher than the level of the vinegar inside the jar but the jam jar does not float. Cover the saucepan with a lid and bring the water to the boil. Now turn down the heat so that the water boils gently and continue the gentle boiling for 20 minutes.

While the vinegar and iron are reacting, prepare a solution of washing soda, as follows.

Preparing a solution of washing soda

Add a heaped tablespoonful of washing soda crystals to a jam jar that has been half-filled with water. Stir to dissolve the crystals; this will take several minutes. The solution will not become completely clear unless you use distilled water, but this does not matter

provided that the large transparent washing soda crystals disappear. Label this jar 'washing soda solution'.

Ignoring some water molecules that are also included in its crystals washing soda is disodium carbonate, Na_2CO_3. Write an equation for the dissolution of washing soda in water.

The equations that you wrote in answering Question 13.1 suggest that disodium carbonate will dissolve in water to form the sodium and carbonate ions listed in Table 13 1:

$$Na_2CO_3(s) \longrightarrow 2Na^+(aq) + CO_3^{2-}(aq) \qquad (13.2.2)$$

This process does happen, but there is a complication. Some of the carbonate ions that are formed then undergo a reaction with water and produce hydroxide ions, $OH^-(aq)$:

$$CO_3^{2-}(aq) + H_2O(l) \longrightarrow HCO_3^-(aq) + OH^-(aq) \qquad (13.2.3)$$

The ion $HCO_3^-(aq)$ that is produced at the same time was once called the bicarbonate ion, but the modern approved name is the hydrogen carbonate ion. So washing soda solution contains both carbonate and hydroxide ions. It is the hydroxide ions that give the solution its soapy feel.

Task 1 Considering the reaction between iron and vinegar

(a) When the 20 minute boiling period is over, turn off the heating beneath the saucepan, take off the lid and, using a dry cloth for protection, remove the jam jar from the saucepan. Observe the nails and the solution carefully and record your observations in Table 13.2.1.

(b) In Section 11, an acid was described as a substance containing atoms of hydrogen that could be replaced by those of a metal. If an iron atom can replace two hydrogen atoms, write a word reaction and then a chemical equation for the reaction that you observed between iron nails and vinegar.

(c) Solutions of salts usually contain aqueous ions. Write an equation for the dissolution in water of the salt that you named and gave a formula for in part (b). ◀

After the jar and its contents have cooled for five minutes, pour the clear solution into another jam jar, leaving the nails and any residue behind. When you have collected the solution, label it Solution A.

Table 13.2.1 For recording observations of reactions in Tasks 1 and 2.

Task	Reaction	Observations
1	iron nails + vinegar	
2a	solution A + hydrogen peroxide	
2b	solution A + hydrogen peroxide + washing soda	
2c(i)	solution A + washing soda	
2c(ii)	solution A + washing soda + hydrogen peroxide	
2d	solution A + washing soda and allow to stand for an hour	

Read the comments on Task 1 before continuing

Task 2 Reactions involving iron ions

This task involves a series of reactions using the solutions that you have prepared. Observe the reactions carefully, and note down in Table 13.2.1 whether solutions or solid precipitates are formed, any colour changes that occur, whether any gas is evolved, and so on. The colour of solutions and presence of suspended particles are often most easily seen against a white background.

(a) Transfer two teaspoonfuls of Solution A to a clean jam jar. Add half a teaspoonful of hydrogen peroxide solution and swirl the jar. Keep this solution for part (b).

(b) To the jam jar containing the solution made in part (a), add two teaspoonfuls of the washing soda solution and stir.

(c) (i) Transfer six teaspoonfuls of Solution A to another jam jar. Now, using a second teaspoon, add washing soda solution to it a teaspoonful at a time, stirring between additions with the first teaspoon. Note what happens initially. At some point, the solution should become pale yellow, and the addition of further washing soda solution will then quickly produce dark blue–green solid particles within the solution. Stop adding washing soda solution at this point.

(ii) Now add a half teaspoonful of hydrogen peroxide solution and stir.

(d) Repeat part (c) but stop at the point where the dark blue–green solid appears. Then leave the solution to stand for an hour or two, and note down what happens. ◄

Disposal of chemicals

When you have completed a chemistry experiment, you need to consider carefully how to dispose safely of your waste solutions and any solids that they contain. After this experiment, dispose of your waste solutions and the solids that they contain by washing them down the drain with plenty of tap water. The remains of the iron nails can be wrapped in newspaper and put into your dustbin.

Task 3 Analysis of results: explaining your observations

This task requires you to try to account for the various changes that you observed in the chemical reactions that you carried out in each of the parts of Task 2.

(a) What form of iron was produced when hydrogen peroxide was added to iron diacetate (Solution A)?

(b) In part (b), it was the OH^- ions in the washing soda solution that reacted with the aqueous iron ions. What substance do you think was produced in this reaction? Write an equation for the reaction.

(c) (i) What gas do you think was evolved when the washing soda solution was added to solution A? The initial precipitate was formed by reaction of the iron ions present with the carbonate ions in the washing soda: write an equation for this reaction.

(ii) What does the colour change of the precipitate suggest happened when hydrogen peroxide was added to the blue–green precipitate formed in part (c)(i)?

(d) Can you suggest why, in this experiment, the same change was observed after leaving the solution to stand for a few hours as was brought about by the hydrogen peroxide in the previous experiment? ◄

Experiment 2: Ions and electrolysis

Aims

This practical work is designed to reinforce and provide physical demonstrations of some of the important ideas found in the book:

- that some substances that dissolve in water greatly enhance its conductivity whereas others do not;
- that conduction is associated with chemical changes at the electrodes in the solution.
- that those changes are sometimes more complicated than the simple discharge of the ions that are formed by the dissolved substance.

Introduction

Water, and solutions of substances in it, conduct electricity when they contain significant amounts of ions. In these cases, conduction is accompanied by chemical reactions at the electrodes. In this activity, we are asking you to detect conduction by looking for signs of reactions taking place.

> ***Safety precautions***
>
> In addition to the precautions given in Section 6 of the *Practical work booklet* care is needed when handling some of the chemicals.
>
> Washing soda may be harmful if swallowed and may irritate eyes on contact.
>
> Table salt may irritate eyes on contact.

Practical procedure

Setting up the equipment

Remove the insulation from both ends of the two pieces of wire and, using the screwdriver, connect the four crocodile clips to the four bare ends.

Now set up the apparatus shown in Figure 13.2.1. You should cut the strip of cardboard to a length that rests comfortably upon the top of your jam jar and then, using the needle, bore two small holes, some 3 cm apart along its long centre-line. These holes should each take a propelling pencil lead with a fairly tight fit. Handle the pencil leads carefully: they are, of course, easily broken.

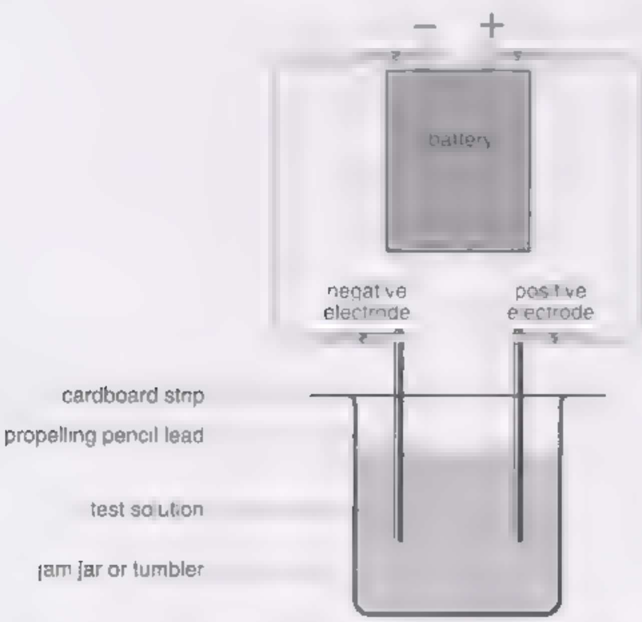

Figure 13.2.1 A simple apparatus for doing electrolysis experiments.

Equipment

NON-KIT ITEMS

six propelling pencil leads (this allows for four breakages!)

four small crocodile clips with screw fittings (obtainable from an electrical shop)

two pieces of insulated wire each 20 cm long, such as that found in standard electric flex

9 volt battery

small screwdriver

needle

two small jam jars or glass tumblers

strip of stiff cardboard about 2 cm wide

paper towels

two teaspoons

KIT ITEM

indicator papers, cut in half lengthways

Materials

NON-KIT ITEMS

distilled or deionized water

tap water

table salt

washing soda crystals

white sugar

Task 1 Electrolysis of various liquids

You should now attempt the electrolysis of the liquids specified in parts (a) to (e) below. In each case you should set up the apparatus shown in Figure 13.2.1 with one crocodile clip disconnected from the battery. Choose the one most convenient for your particular apparatus. When you are ready to make your observations, make the final connection and then note carefully what happens at each electrode. Record your observations, and the results of any other tests that you are asked to do, in Table 13.2.2. The pencil lead connected to the negative terminal of the battery is the negative electrode; the pencil lead connected to the positive terminal of the battery is the positive electrode.

Between each part of the task, put the electrodes out of harm's way in a second jam jar of tap water. Rinse the first jam jar with tap water, and dry it with a paper towel.

(a) Pour tap water into the jam jar until it is about three-quarters full. Attempt to electrolyse it using the arrangement of Figure 13.2.1.

(b) Now attempt the electrolysis using deionized or distilled water instead of tap water.

> *Indicator papers*
>
> In Section 2 you were introduced to the use of blue litmus as a test for acids — they turn it red.
>
> There are several other compounds that can be used as a test for an acid, and the indicator papers in your kit are impregnated with one of them. When the indicator paper turns yellow-pink-purple it is has the same meaning as blue litmus turning red. When the indicator paper turns green-blue, it is has the same meaning as red litmus turning blue.
>
> You will be using the indicator papers again if you decide to study Block 8. To ensure that you don't run out, we recommend that you cut the indicator papers in half lengthways before using them.

(c) Pour deionized water into a jam jar until it is about three-quarters full (you can use the water from part (b)). Add a teaspoonful of table salt and stir to dissolve. Now attempt the electrolysis. After 30 seconds, place the end of a strip of indicator paper in the liquid as close as possible to the negative electrode. Note any change in colour. During this particular electrolysis, you may become aware of a smell that is probably familiar from contact with swimming pools and household bleach. This is due to a gas produced at one of the electrodes; what gas do you think it is?

> Avoid deep inhalation of this gas and ventilate the room thoroughly afterwards

(d) Repeat what you did in part (c) but use sugar in place of table salt, and do not bother with the indicator paper test.

(e) Repeat what you did in part (c) but use washing soda in place of table salt and do not bother with the indicator paper test. ◄

Table 13.2.2 Record of observations of electrolysis experiments

Task	Substance	Negative electrode	Positive electrode	Additional remarks
1a	tap water			
1b	distilled or deionized water			
1c	table salt solution			
1d	sugar solution			
1e	washing soda solution			

> ***Disposal of chemicals***
>
> When you have completed a chemistry experiment, you need to consider carefully how to safely dispose of your waste solutions and any solids that they contain. In this part of the activity you have just used solutions of salt, sugar and soda, and these can be rinsed away with tap water in a sink.

Task 2 Analysis of results: explaining your observations

You should now try to account for your observations in Task 1 in terms of the chemistry that you have learned in this block, particularly in Section 13.

(a) What does the absence of any signs of reactions in parts (b) and (d) of Task 1 indicate about the liquids that you were trying to electrolyse?

(b) Your observations in part (a) of Task 1 will depend on where you live. In some places tap water behaves differently from distilled or deionized water when you try to electrolyse it and in some places it behaves in the same way. Why do you think this might be?

(c) In the electrolysis of hydrochloric acid (Section 13.2) and copper dichloride solution (Question 13.2), the ions that are formed in solution — $H^+(aq)$, $Cl^-(aq)$ and $Cu^{2+}(aq)$ — are discharged at the electrodes as hydrogen gas, chlorine gas and copper metal, respectively. Did your solution of table salt (sodium chloride) behave in a similar way? If not, how do you explain your observations, including the result of the indicator paper test? (You should bear in mind what you learnt about sodium in Section 12.2 and in the DVD-multimedia Activity 12.1.)

(d) Washing soda is disodium carbonate, Na_2CO_3. How do you account for your observations of the electrolysis of a washing soda solution in part (e) of Task 1? ◀

Activity 14.1 Prediction using the Periodic Table

This activity applies the predictive skills that you acquired when studying the DVD-multimedia activity 12.1. You will use the mini Periodic Table of Figure 12.7 to deduce some of the properties of radium (symbol Ra, serial number 88).

(a) Marie Curie noticed that the chemical properties of radium are like those of barium, how is this consistent with Figure 12.7?

(b) What do you expect the valency of radium to be? Write formulae for radium hydride, fluoride, chloride, bromide and oxide

(c) Write an equation for the reaction that occurs when radium chloride dissolves in water and forms aqueous ions.

(d) Would you expect the relative atomic mass of radium to be greater or less than that of barium?

Activity 15.1 Reviewing your study of Block 6: techniques for understanding

This block has told a story that is logical but lengthy, and full of new ideas. To understand these ideas thoroughly, you must appreciate their relationship, both to each other and to what you knew before. In this activity we ask you to consider what techniques *you* used help you to understand them.

We suggest that you choose two or three of the new ideas that you had particular difficulty with at first. Then ask yourself how you tried to understand these ideas, and how successful your attempts proved to be. Make a note of the range of techniques that you used. You may well have found that different techniques worked on different occasions, since not all difficulties are the same. Try to come up with more than just 'I slept on it, and in the morning it made sense'. This is one tactic that often works, but it should not be relied on as the only solution! By doing this activity, you should be able to clarify what works for you. You will then be able to test your techniques out on any difficult ideas that you meet in later Blocks

To get you started, here are a few possible techniques.

1 Try to understand the meaning of a concept by studying its definition very carefully.

2 Try to understand a concept by tackling questions and activities that involve it.

3 Try to get to grips with the concept by drawing diagrams.

You can probably add other techniques that you have found helpful. In the comments on the activity, we shall consider the advantages and drawbacks of these and other techniques, using the mole as an example. We have chosen the mole because this is a concept that many students find especially difficult on a first encounter.

Comments on activities

Activity 2.1

We have not provided a summary of this DVD-video activity, because the reactions that are demonstrated are all described in Section 2. You may like to scan quickly through the section to identify the reactions that you have seen demonstrated in the DVD-video sequence. You may also have noticed Dr Johnson's blunder when he spoke of caliche as a mineral! A mineral has a single characteristic composition that varies only within narrow limits (Block 3). Caliche contains at least two minerals in this sense (sodium nitrate and sodium chloride), so it is better spoken of as a 'material'.

Activity 2.2

There are no comments on this activity

Activity 4.1

Task 1

Here is a sample response from a student:

> Weigh the apparatus at the start. Pass hydrogen chloride gas into the water in the beaker until the weight of the apparatus has increased by an amount large enough to yield accurate results, and then weigh it again. Then add silver nitrate solution to the solution of hydrogen chloride. Filter off the silver chloride and weigh it

A laboratory manual would give you more detailed instructions on how to proceed:

> Set up the apparatus as in Figure 4.1.1, with about 50 cm^3 of water in the glass beaker. Weigh the apparatus, and then connect it to a supply of hydrogen chloride. Expose the water in the beaker to hydrogen chloride gas until the mass of the apparatus has increased by about a gram. Weigh the apparatus accurately again. Then ease out the bung and tubes, and rinse the gas inlet tube inside and outside with water so that the washings fall into the beaker. Add silver nitrate solution, drop by drop, to the liquid in the beaker. A white precipitate should appear as the chlorine in the dissolved hydrogen chloride is converted into silver chloride. When no more precipitate is being formed as you do this, stop the addition. Then filter off the solid silver chloride, dry it and weigh it.

Task 2

(a) The tube acts as a safety valve in case of sudden changes in pressure.

(b) Hydrogen chloride dissolves rapidly. If the tube went straight into the water, the water might be sucked right back up the tube, just as it rushed to fill the gas jar in Figure 2.14.

(c) When the inlet tube is eased out, it will be wet with hydrogen chloride solution. If removed without washing, it would take some of the hydrogen chloride that had dissolved with it. Not quite *all* of the chlorine in the dissolved hydrogen chloride would then end up as silver chloride, and the results would be inaccurate. Washing makes sure that all of the dissolved hydrogen chloride is collected in the beaker.

(d) It is important to convert *all* of the chlorine in the hydrogen chloride into silver chloride.

(e) If the silver chloride is wet when it is weighed, it will contain an unknown mass of water, and you would not know what the mass of the silver chloride was

Task 3

(a) From Question 4.2, silver chloride is composed of 24.7% chlorine. So the mass of chlorine in 3.937 g of silver chloride is

$$\frac{24.7}{100} \times 3.937\,\text{g} = 0.972\,\text{g (to three sig. figs)}$$

(b) The dissolved hydrogen chloride had a mass of 1.000 g. Its chlorine became the 0.972 g of chlorine contained in the silver chloride, as calculated in part (a). Thus 1.000 g of hydrogen chloride contains 0.972 g of chlorine and, by difference, 0.028 g of hydrogen. These figures tell us that hydrogen chloride is composed of 97.2% chlorine and 2.8% hydrogen.

(c) The percentage composition tells us that, in 100 g of hydrogen chloride,

2.8 g of hydrogen are combined with 97.2 g of chlorine

So 1.00 g of hydrogen is combined with

$$\frac{97.2\,\text{g}}{2.8} = 35\,\text{g of chlorine (to two sig. figs)}$$

Activity 6.1

(a) Figure 6.1.2 shows a suitable design. The conversion of methane into carbon dioxide and water vapour takes place in the heated tube. A U-tube of calcium chloride absorbs the water vapour, and a second U-tube of soda lime then mops up the carbon dioxide. Because of its water-absorbing tendencies, the soda lime tube must come second, after water vapour has been removed by the calcium chloride

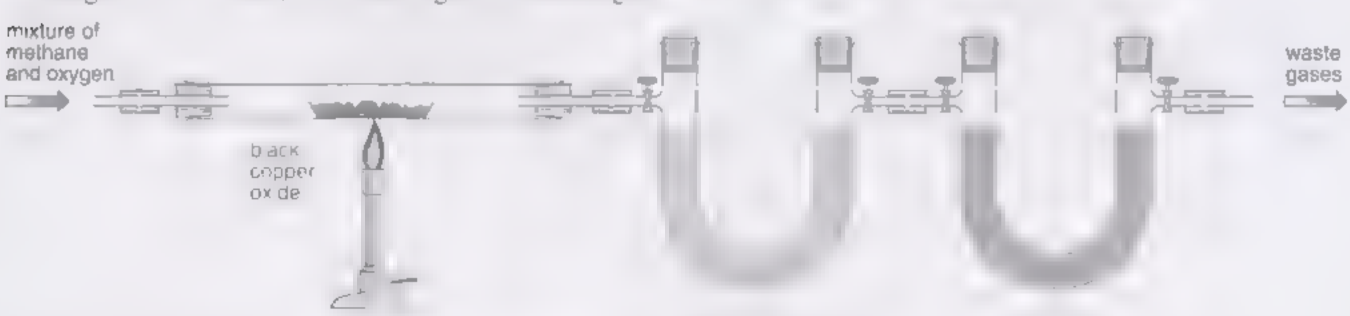

Figure 6.1.2 Apparatus for finding the chemical composition of methane

The two U-tubes are filled with chemicals and weighed with the taps shut before incorporation into Figure 6.1.2. The taps are opened during the experiment, and shut at the end when the U-tubes are removed and reweighed.

(b) The calculation of the composition of methane from the data given proceeds as follows. The methane that has been decomposed has produced 0.500 0 g of water and 0.611 7 g of carbon dioxide

Since water contains 11.2% hydrogen, 0.500 0 g of water contains

$$\frac{11.2}{100} \times 0.500\,0\text{ g} = 0.056\,0\text{ g of hydrogen}$$

Since carbon dioxide contains 27.3% carbon, 0.611 7 g of carbon dioxide contains

$$\frac{27.3}{100} \times 0.611\,7\text{ g} = 0.167\text{ g of carbon}$$

Note that the masses of hydrogen and carbon are both expressed to three significant figures, because the percentages were given to three significant figures. Thus the methane that decomposed contained 0.167 g of carbon and 0.056 0 g of hydrogen, so its total mass was (0.167 + 0.056 0) g, or 0.223 g.

Since 0.223 g of methane contains 0.167 g of carbon,

$$\text{percentage of carbon} = \frac{0.167\text{ g}}{0.223\text{ g}} \times 100\% = 74.9\%$$

$$\text{percentage of hydrogen} = (100 - 74.9)\% = 25.1\%$$

(c) Here are the notes made by one student:

(i) To find the mass of an element in a certain mass of a compound, I divide the percentage composition of the element by 100 and multiply by the mass of the compound. Example: 11.2% hydrogen in water, so 0 500 0 g of water contains

$$\frac{11.2}{100} \times 0.500\,0\text{ g} = 0.056\,0\text{ g of hydrogen}$$

(ii) To find the percentage composition from the mass of a compound and the mass of one of the elements it contains, I divide the mass of the element by the mass of the compound and multiply by 100%. Example: 0.223 g of methane contains 0.167 g of carbon, so the percentage of carbon is

$$\frac{0.167\text{ g}}{0.223\text{ g}} \times 100\% = 74.9\%$$

This is one of a number of types of calculation that you will have to do over and over again in chemistry. It is handy to gather notes about the general procedures together in one place for easy reference, and you might like to append your notes on how to do this type of calculation to your glossary of chemicals. You can then add notes of other general procedures for calculations as you meet them.

Activity 6.2

We have not provided a summary of this DVD-video activity, because the reactions that are demonstrated are all described in Section 3–6. You may like to scan quickly through these sections to identify the reactions that you have seen demonstrated in the DVD-video sequences.

Activity 6.3

(a) (i) The reaction between silver nitrate and hydrochloric acid was used (Section 3.1) to illustrate the law of conservation of mass. This is statement F.

(ii) These observations were accumulated in Sections 3.2–3.4. They show that no matter how a chemical compound is made, it has a fixed composition — statement B

(iii) This observation was our main example of the taking apart of a chemical compound into constituents. It therefore made a vital contribution to our formulation of statement G. A further contribution was made by noting that no one has succeeded in taking apart the constituents themselves (hydrogen and oxygen). These are therefore chemical elements.

(b) This argument was first put together in Section 5.3, repeated in Activity 6.2, and commented on in a more general way in Sections 6 and 6.5. The answers are (1) C; (2) A; (3) E and (4) D. The second column of Table 6.3.1 then becomes.

> Suppose that chemical elements are composed of atoms, that all the atoms of a particular element are identical, especially in mass, that atoms of carbon have a different mass from atoms of oxygen, and that chemical combination occurs by the union of the atoms of the elements in simple whole number ratios.
>
> It follows that *if* every carbon atom is combined with one oxygen atom in carbon monoxide (CO), then every carbon atom must be combined with two oxygen atoms in carbon dioxide (CO_2), and three oxygen atoms have the same mass as four carbon atoms
>
> But we do not *know* that carbon monoxide is CO. So we have a dilemma. We cannot get relative atomic masses unless we know chemical formulae, and we cannot get chemical formulae unless we know relative atomic masses.

(c) Table 6.3.2 is a rewritten version of Table 6.3.1, with evidence from copper oxides in place of evidence from carbon oxides.

The data for the copper oxides clearly corroborate the atomic theory. The important point to keep in mind is that it is not enough to set up an hypothesis to explain observations and measurements; that hypothesis then needs further testing.

Table 6.3.2 A version of Table 6.3.1 that refers to copper oxides rather than oxides of carbon

Experimental evidence	Interpretation
When 0.252 g of oxygen forms black copper oxide, it combines with 1.000 g of copper; when it forms red copper oxide, it combines with 2.000 g of copper. These two masses of copper are in the exact ratio 1 : 2	Suppose that chemical elements are composed of atoms, that all the atoms of a particular element are identical, especially in mass, that atoms of copper have a different mass from atoms of oxygen, and that chemical combination occurs by the union of the atoms of the elements in simple whole number ratios. It follows that *if* every oxygen atom is combined with one copper atom in black copper oxide (CuO), then every oxygen atom is combined with two copper atoms in red copper oxide (Cu_2O), and four oxygen atoms have roughly the same mass as one copper atom. But we do not *know* that black copper oxide is CuO. So we have a dilemma. We cannot get relative atomic masses unless we know chemical formulae, and we cannot get chemical formulae unless we know relative atomic masses.

Activity 6.4

Here is the response produced by one student:

> The most unusual feature is the 85% level of carboxyhaemoglobin in the dead woman's blood. Figure 6.4.1 shows that hardly any non-fire victims are found with figures as high as this. It is also strange that the husband's level (15%) is so different when he slept in the same caravan as his wife. Also, Figure 5.5 suggests that his symptoms are surprisingly severe for such a value. Although dead victims of carbon monoxide poisoning are very occasionally found at a 15% level (Figure 6.4.1), we would expect headache rather than unconsciousness. However, some carbon monoxide may have been lost from the blood during respiration before the measurement was made.
>
> I suggest that the wife was murdered by the husband, who inhaled some carbon monoxide, either accidentally or so as to divert suspicion from himself. To substantiate this, further evidence is needed. (*147 words*)

In fact, under police questioning the man confessed to murdering his wife in her sleep by exposing her to a stream of carbon monoxide from a gas cylinder that he had obtained at his workplace.

Activity 6.5

A sample answer from a student is given below:

> The gas whose properties are described is carbon dioxide, not carbon monoxide. It is carbon dioxide that is produced by the reaction between marble chips and hydrochloric acid. The gas is colourless, odourless and much denser than air, so it can be retained by, and poured out of, jugs. Carbon monoxide is also colourless and odourless, but its density is similar to that of air, and so it could not be stored in jugs. Moreover, had Mr Reeder been able to put a lighted match into a stock of it, he would have been engulfed in flame. The extract could be made almost entirely correct by substituting the words carbon dioxide for carbon monoxide. However, this change makes the murder plan more doubtful because the dioxide is much less toxic. It would then resemble a way of suffocating someone by replacing the oxygen in the air with carbon dioxide, for which a jugful would be inadequate. (*156 words*)

Note how this sample answer is structured. It starts with a clear statement of the main error in the extract — the confusion between carbon dioxide and carbon monoxide. It then indicates how the described properties correctly apply to carbon dioxide, and points out which properties fit carbon monoxide and which don't. Finally it indicates why carbon dioxide would not have been a suitable gas for this murder attempt. There are other ways that the answer could be structured, and you should compare the way that you structured your paragraph with the sample here.

Note that in order to criticize somebody else's science, you need to know about the science that is being discussed, so that you can decide where the facts are right and where they are wrong, or maybe where important relevant facts have been overlooked. You also need to judge whether any deductions that are made are justified by the facts, and to consider whether there is another interpretation that may be better. You may hesitate to suggest that there are errors and misconceptions in articles that you read or programmes that you watch or listen to, but as the Edgar Wallace extract indicates, the printed word is not always correct! So be prepared to question and check other sources of information when there appear to be inconsistencies. A willingness to question and to check is an important characteristic of a successful scientist.

Activity 7.1

The answers to the questions in Figure 7.1.1 are as follows.

(a) One law is Boyle's law; at constant temperature,

$$PV = \text{constant}$$

The other law is Charles' law; at constant pressure,

$$\frac{V}{T} = \text{constant}$$

Note that T represents *absolute* temperature.

(b) Before the pressure is increased, the drumming of the gas molecules on the surface of whatever imposes the pressure (e.g. mercury or a piston) keeps that surface at bay and the volume constant. But when the pressure increases, the drumming becomes insufficient, the surface advances and the volume decreases. On the other

hand, an increase in temperature increases the speed of the molecules, and therefore the intensity of the drumming, so the surface retreats and the volume increases.

(c) The gas chosen was oxygen. Since the measurements were made on a bulb immersed in ice–water, the gas was already at 0 °C, the temperature corresponding to STP. The volume did not therefore need correction for a change in temperature, so the correction could be made by using Boyle's law alone.

(d) The least dense gas is hydrogen; this was used to lift airships such as the *Hindenburg* (Figure 2.20). The most dense gas is chlorine, the first known war gas.

(e) Gay-Lussac's law came first, and led to Avogadro's hypothesis, which tells us that the equal volumes of hydrogen and oxygen at the same temperature and pressure contain the same number of molecules.

(f) Cannizzaro's principle states that the mass of one atom of an element is the smallest mass of that element found in any molecule containing it. In Section 8.3 and Activity 8.3 it allowed us to conclude that the molecules in hydrogen and oxygen gases are diatomic.

Activity 7.2

(a) We shall write pressures in mm of mercury as mmHg. Applying Boyle's law at 27 °C:

$$1\,140\text{ mmHg} \times (\text{volume at } 1\,140\text{ mmHg}) = 760\text{ mmHg} \times 600\text{ cm}^3$$

$$\text{volume at } 1\,140\text{ mmHg} = \frac{760\text{ mmHg} \times 600\text{ cm}^3}{1140\text{ mmHg}}$$

$$= 400\text{ cm}^3$$

Now 27 °C is (273 + 27) K or 300 K, and 327 °C is (273 + 327) K or 600 K. Applying Charles' law at 1 140 mmHg.

$$\frac{\text{volume at 600 K}}{600\text{ K}} = \frac{\text{volume at 300 K}}{300\text{ K}}$$

$$= \frac{400\text{ cm}}{300\text{ K}}$$

$$\text{volume at 600 K} = \frac{400\text{ cm}^3 \times 600\text{ K}}{300\text{ K}}$$

$$800\text{ cm}^3$$

(b) This same answer is obtained by applying Charles' law first and Boyle's law second. Applying Charles law at 760 mmHg of mercury:

$$\frac{\text{volume at 600 K}}{600\text{ K}} = \frac{\text{volume at 300 K}}{300\text{ K}}$$

$$= \frac{600\text{ cm}^3}{300\text{ K}}$$

$$\text{volume at 600 K} = \frac{600\text{ cm}^3 \times 600\text{ K}}{300\text{ K}}$$

$$= 1\,200\text{ cm}^3$$

Now applying Boyle's law at 600 K,

$$1\,140\text{ mmHg} \times (\text{volume at } 1\,140\text{ mmHg}) = 760\text{ mmHg} \times 1\,200\text{ cm}^3$$

$$\text{volume at } 1\,140\text{ mmHg} = \frac{760\text{ mmHg} \times 1\,200\text{ cm}^3}{1\,140\text{ mmHg}}$$

$$= 800\text{ cm}^3$$

This is the same final volume as calculated when the two laws were applied in the reverse order in part (a): the order of the calculations does not matter.

(c) Here are notes made by one student:

Boyle's law: PV = constant when T is fixed. So

$$\text{initial } P \times \text{initial } V = \text{final } P \times \text{final } V$$

If I know any three of the quantities in the equation then I can work out the fourth

Charles' law: V/T = constant when P is fixed. So

$$\frac{\text{initial } V}{\text{initial } T} = \frac{\text{final } V}{\text{final } T}$$

Again if I know any three of the quantities then I can work out the fourth quantity

If you are compiling a set of 'typical' calculations, as we suggested in Activity 6.1c, then you should include your notes about Boyle's law and Charles' law with them.

Activity 8.1

Using case 3 as an example, if each hydrogen molecule combines with two chlorine molecules, then the number of hydrogen molecules in the hydrogen box must be half the 10 billion in the chlorine box. This number is therefore 5 billion: in a given volume, at a fixed temperature and pressure, the number of hydrogen molecules is *half* the number of chlorine molecules. The answers for the three cases are therefore.

case 1 20 billion hydrogen molecules; twice
case 2 10 billion hydrogen molecules; the same as
case 3 5 billion hydrogen molecules, half

Activity 8.2

(a) The steps used in Section 8.3 are as follows:

1 Assume there are N molecules per litre of any gas, and calculate the masses of one molecule of each type of gas by dividing the mass per litre (the density) by N.
2 Use these values of the masses of the molecules together with known values of the percentage of hydrogen in each molecule to calculate the mass of hydrogen in each molecule.
3 Identify the molecule that contains the smallest mass of hydrogen and assume that it only contains a single atom of hydrogen.
4 Calculate the number of hydrogen atoms in the other molecules by dividing the mass of hydrogen that they contain by the smallest mass of hydrogen.

To generalize this list of steps so that it can be applied to any element, you simply need to replace 'hydrogen' in the list above by 'element X'. In the next part of this activity, element X will be carbon, and in a later activity it will be oxygen.

Table 8.2.2 Completed table for Activity 8.2b.

Gas	Density at STP/g litre^{-1}	Mass of molecule/g	Percentage of carbon by mass/%	Mass of carbon per molecule/g	Number of carbon atoms in molecule
methane	0.716	$\frac{0.716}{N}$	74.9	$\frac{0.536}{N}$	1.00
carbon monoxide	1.25	$\frac{1.25}{N}$	42.9	$\frac{0.536}{N}$	1.00
ethane	1.34	$\frac{1.34}{N}$	79.9	$\frac{1.07}{N}$	2.00
carbon dioxide	1.96	$\frac{1.96}{N}$	27.3	$\frac{0.535}{N}$	1.00
propane	1.97	$\frac{1.97}{N}$	81.7	$\frac{1.61}{N}$	3.00

(b) Step 1 in the list in part (a) allows us to complete column 3 of Table 8.2.1, as shown in Table 8.2.2. Step 2 allows us to calculate the masses of carbon per molecule shown in column 5. So for example, since the mass of the methane molecule is $\frac{0.716}{N}$ g, and since 74.9% of the mass is carbon, then the mass of carbon in the molecule is $\frac{0.716}{N}$ g $\times$ $\frac{74.9}{100}$ = $\frac{0.536}{N}$ g. Using step 3 we note that methane, carbon monoxide and carbon dioxide all contain the same lowest value of the mass of carbon per molecule, $\frac{0.536}{N}$ g, and we assume that these molecules all contain just a single atom of carbon each. Finally, step 4, we divide the two other masses of carbon per molecule in column 5 by the smallest mass, $\frac{0.536}{N}$ g, and find that ethane contains two carbon atoms and propane contains three.

Note that the general procedure that was deduced from studying hydrogen-containing compounds in Section 8.3 applied equally well to the carbon-containing compounds in Table 8.2.1. This is the beauty of being able to deduce a general procedure like this; it not only simplifies subsequent calculations but also aids understanding of the principles involved. You should keep a note of it with the notes that you made of other types of calculation in Activities 6.1 and 7.2.

(c) When allied with the results of Table 8.1, the results from (b) give the formulae for methane, ethane and propane as CH_4, C_2H_6 and C_3H_8, respectively.

Activity 8.3

The four steps identified in Activity 8.2a can be used equally well to find the numbers of oxygen atoms in the set of compounds in Table 8.3.1, and the results are shown in Table 8.3.2. The figures in the final column are obtained by dividing the mass of oxygen in each molecule (column 5) by $\frac{0.714}{N}$, the smallest mass of oxygen found in these and, as it turns out, any other molecules. Ozone consists of molecules which contain three oxygen atoms (O_3) as opposed to the O_2 molecules of the oxygen gas that you are used to.

Table 8.3.2 Completed table for Activity 8.3

Gas	Density at STP/g litre^{-1}	Mass of molecule/g	Percentage of oxygen by mass/%	Mass of oxygen per molecule/g	Number of oxygen atoms in molecule
oxygen	1.43	$\frac{1.43}{N}$	100	$\frac{1.43}{N}$	2.00
water vapour	0.804	$\frac{0.804}{N}$	88.8	$\frac{0.714}{N}$	1.00
carbon monoxide	1.25	$\frac{1.25}{N}$	57.1	$\frac{0.714}{N}$	1.00
carbon dioxide	1.96	$\frac{1.96}{N}$	72.7	$\frac{1.42}{N}$	1.99
ozone	2.14	$\frac{2.14}{N}$	100	$\frac{2.14}{N}$	3.00
sulfur dioxide	2.86	$\frac{2.86}{N}$	49.9	$\frac{1.43}{N}$	2.00

Activity 10.1

(a) The mass of water vapour is the increase in the mass of the calcium chloride tube. This is (21.558 – 20.837) g, or 0.721 g.

(b) Since water is 88.8% hydrogen and 11.2% hydrogen,

$$\text{mass of hydrogen} = \frac{11.2}{100} \times 0.721\,\text{g} = 0.080\,8\,\text{g}$$

$$\text{mass of oxygen} = \frac{88.8}{100} \times 0.721\,\text{g} = 0.640\,\text{g}$$

Thus the decomposed arsine contained 0.080 8 g of hydrogen.

(c) The oxygen mass calculated in part (b) tells us that the copper oxide boat lost 0.640 g of oxygen. But the boat increased in mass by (23.729 – 22.368) g, or 1.361 g. This increase is the mass of the arsenic picked up from the arsine less the 0.640 g oxygen lost by the copper oxide. Thus the arsenic from the arsine had a mass of (1.361 + 0.640) g, or 2.001 g.

(d) The mass of hydrogen in the decomposed arsine is the hydrogen content of the water vapour calculated in part (b). This is 0.080 8 g.

(e) From parts (c) and (d), the decomposed arsine contained 2.001 g of arsenic and 0.080 8 g of hydrogen, and so the total mass of decomposed arsine was (2.001 + 0.0808) g, or 2.082 g. Thus

$$\text{percentage of arsenic} = \frac{2.001}{2.082} \times 100\% = 96.1\%$$

$$\text{percentage of hydrogen} = \frac{0.0808}{2.082} \times 100\% = 3.88\%$$

(f) From the percentage composition,

96.1 g of arsenic are combined with 3.88 g of hydrogen

1 g of arsenic is combined with $\frac{3.88\,\text{g}}{96.1}$ of hydrogen

Now 1 mole of arsenic atoms, As, has a mass of 74.9 g, so

1 mole of As is combined with $\frac{74.9 \times 3.88\,\text{g}}{96.1}$ of hydrogen

= 3.02 g of hydrogen

1 mole of hydrogen atoms, H, has a mass of 1.01 g, so 3.02 g of hydrogen contain $\frac{3.02\,\text{g}}{1.01\,\text{g}}$ moles of H, or 2.99 moles of H. So in arsine, every mole of As is combined with 3 moles of H, which means that the empirical formula is AsH_3.

(g) The ratio of the density of arsine to that of hydrogen at STP is (3.50/0.089 9) or 38.9. Using Equation 10.7, the relative molecular mass is double this (77.8). This is virtually identical with the relative molecular mass of an AsH_3 unit [74.9 + (3 × 1.01) = 77.9]. The molecular formula of arsine is therefore identical with its empirical formula AsH_3.

(h) Since one arsenic atom combines with three hydrogen atoms, the valency of arsenic is three.

(i) Hydrogen gas consists of H_2 molecules, so the initial unbalanced equation is:

$$AsH_3(g) \longrightarrow As(s) + H_2(g)$$

We can balance hydrogen by bringing the hydrogen atoms to six on each side if we replace AsH_3 by $2AsH_3$, and H_2 by $3H_2$.

$$2AsH_3(g) \longrightarrow As(s) + 3H_2(g)$$

Now we balance arsenic by replacing As by 2As.

$$2AsH_3(g) \longrightarrow 2As(s) + 3H_2(g) \qquad (10.1.1)$$

(j) The decomposition reaction in Equation 10.1.1 shows that 2 molecules of gaseous arsine yield 3 molecules of gaseous hydrogen. Avogadro's hypothesis tells us that the word *molecule* can be replaced by the word volume: 2 volumes of arsine gives 3 volumes of hydrogen at the same temperature and pressure. If 2 volumes (10 cm^3) of arsine disappear, they will be replaced by 3 volumes (15 cm^3) of hydrogen. So the final volume is 15 cm^3 and it consists solely of hydrogen; the solid arsenic will be deposited on the walls of the container or on the mercury.

This activity provides examples of several important tasks that you should be able to carry out. These include:

(f) finding empirical formulae from percentage composition;

(g) finding molecular formulae from empirical formulae and gas densities,

(h) working out valencies,

(i) balancing chemical equations;

(j) doing calculations involving reacting volumes of gases

You might find it helpful to include a worked example of each of these, together with your advice to yourself on how to carry out each task, along with your notes from Activities 6.1, 7.2 and 8.2.

Activity 10.2

(a) You establish the mass of water vapour that was formed using item 2.

(b) The calculation of the masses of hydrogen and oxygen assumes that water has a fixed percentage composition by mass: item 4.

(c) The calculation of the mass of arsenic in arsine relies on a mass of oxygen obtained using the chemical composition of water, and on the idea that the masses of arsenic and oxygen are unaffected by chemical changes: items 1 and 4.

(d) To find the mass of hydrogen in arsine, what was assumed for arsenic and oxygen in (c) is assumed for hydrogen: items 1 and 4.

(e) The calculation of the percentage composition of arsine draws on (c) and (d), but if we ignore this dependence, it simply calculates a chemical composition: item 4.

(f) The chemical composition of arsine is here converted into a composition expressed as a ratio of the molar

masses of the atoms of arsenic and hydrogen. This ratio gives an empirical formula: items 4 and 9.

(g) Determining the molecular formula of arsine relies on item 7 and the knowledge that hydrogen contains H_2 molecules (item 3)

(h) Determining the valency relies on item 5.

(i) To balance the equation for the decomposition of arsine, one needs item 8; to get the correct products in that equation, one needs item 3.

(j) Determining the volume and composition of the remaining gas draws on the balanced equation obtained in (i), but if one ignores this, the key principle is item 6, which allows us to replace the numbers of molecules in chemical equations by volumes (Section 8.1.1).

Activity 12.1

The key points about chemical periodicity and the Periodic Table that you should take away from this activity are summarized in Section 12.3 of the book.

This activity has given you a lot of practice with the important science skill of classification. When you classify things, you group them according to some particular quality or property. For people, this property might be height or gender. In the case of the chemical elements, you grouped them as solids, liquids or gases, as metals or non-metals, or according to the formulae of compounds such as the highest hydrides.

Why do scientists classify things? Because they hope that the classification will reveal some suggestive order or pattern from which a new theory might emerge. If there is to be order, there has to be an ordering parameter. In this case your ordering parameter was relative atomic mass, at least in the first instance. When you arranged the elements in order of relative atomic mass, you found that members of the classes that your earlier classification generated, turned up at regular intervals. This allowed you to build the Periodic Table and predict the properties of elements. If you study Block 8, you will see how the order expressed in the Periodic Table helped scientists to work out the arrangement of the particles of which atoms are composed. So the classification process that you sampled in Activity 12.1 didn't just bring order to the chemistry of the elements; it also helped to solve one of the most fundamental of scientific problems: the problem of the inner structure of the atom.

Activity 13.1

The experiments demonstrated in this activity are described in the book, and you may like to scan through the book to identify where they occur. Figure 13.1.1 shows a cross-section of the Norfolk lime-kiln that was used as a location during much of this activity.

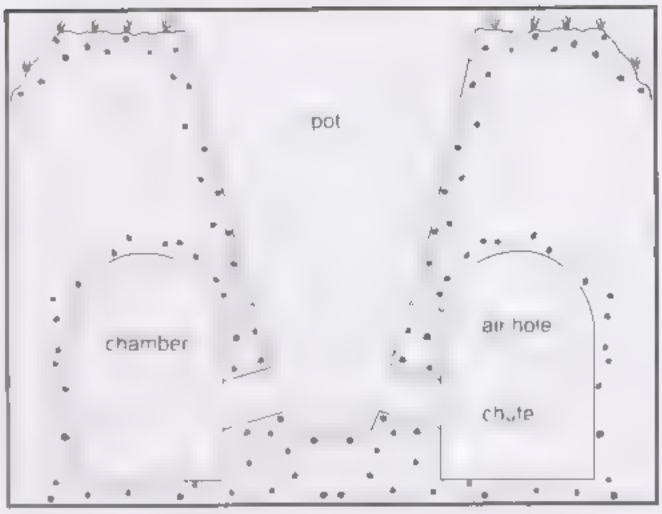

Figure 13.1.1 A cross-section of an old Norfolk lime-kiln When seen in three-dimensions, the sections of chamber to left and right are joined to form a circular room with an arched roof centred on, and surrounding, the lower third of the pot

Activity 13.2

Experiment 1

Task 1

(a) When you removed the jam jar of vinegar and iron nails from the saucepan, you should have seen bubbles of a colourless gas rising from the remains of the iron nails. This gas is hydrogen (Table 13.2.2).

(b) Iron and other metals often react with acids to give hydrogen (Section 2.4.3). The reaction that you observed can be written as:

$$\text{iron} + \text{acetic acid} \longrightarrow \text{iron acetate} + \text{hydrogen} \qquad (13.2.4)$$

As you were told, each iron atom replaces two hydrogen atoms, so the chemical equation is

$$Fe(s) + 2HAc(aq) \longrightarrow Fe(Ac)_2 + H_2(g) \qquad (13.2.5)$$

The iron acetate that is formed is a salt, and it can be obtained from the solution in a solid form by evaporation of the water. In this salt, each iron atom is combined with *two* acetate groups, so the more precise name is iron diacetate.

(c) Equation 13.2.1 shows that each acetate ion carries a single negative charge Because the compound contains one iron to every two acetates, the iron ion that is produced when the dissolution takes place must carry *two* positive charges:

$$Fe(Ac)_2(s) \longrightarrow Fe^{2+}(aq) + 2Ac^-(aq) \qquad (13.2.6)$$

Thus the solution of iron diacetate that is produced when iron dissolves in acetic acid consists of $Fe^{2+}(aq)$ and acetate ions. This suggests another way of writing the equation for the reaction, one that concentrates on the changes undergone by the element iron. It emphasizes the point that iron metal reacts with the aqueous hydrogen ions in the acetic acid to form $Fe^{2+}(aq)$ ions and hydrogen gas:

$$Fe(s) + 2H^+(aq) \longrightarrow Fe^{2+}(aq) + H_2(g) \qquad (13.2.7)$$

Table 13.2.3 Completed version of Table 13.2.1. Record of observations made during experiments with iron ions

Task	Reaction	Observation
1	iron nails + vinegar	gas bubbles coming from iron nails
2a	solution A + hydrogen peroxide	lots of gas bubbles: solution turns red
2b	solution A + hydrogen peroxide + washing soda	orange specks formed
2c(i)	solution A + washing soda	dark blue–green specks formed
2c(ii)	solution A + washing soda + hydrogen peroxide	orange specks appeared immediately
2d	solution A + washing soda and stand	specks turned orange after about 10 minutes

Notice that this equation is correctly balanced even though the charges do not sum to zero on each side of the equation. Firstly, there is one iron and two hydrogens on each side. Secondly, although the total charge on each side is not zero, it does have the *same* value. That value is 2+.

The solution of iron diacetate that you made should have been colourless. This is because the ions $Fe^{2+}(aq)$ and $Ac^{-}(aq)$ that it contains are both colourless or at most very pale. However, besides $Fe^{2+}(aq)$, iron also forms another ion, $Fe^{3+}(aq)$, with a charge of 3+. This has a rusty red colour. Task 2 is concerned with the preparation and reactions of both of these ions of iron.

Task 2

Table 13.2.3 shows the notes made by a student while doing the experiments with iron ions.

Task 3

(a) When hydrogen peroxide is added to iron diacetate solution, a solution with a rusty red colour is produced. This indicates that the colourless $Fe^{2+}(aq)$ ions are converted into orange $Fe^{3+}(aq)$ ions.

(b) In this experiment, Fe^{3+} ions formed by the reaction of hydrogen peroxide with $Fe^{2+}(aq)$ in (a) react with the *hydroxide* ions in washing soda solution and form solid orange iron trihydroxide:

$$Fe^{3+}(aq) + 3OH^{-}(aq) \longrightarrow Fe(OH)_3(s) \qquad (13.2.8)$$

(c) (i) Initially the disodium carbonate reacts with the vinegar to produce carbon dioxide gas. This time the iron ion in the solution is $Fe^{2+}(aq)$, and it is this that reacts with the *carbonate* ions in the washing soda, forming solid particles of iron carbonate, $FeCO_3$, which is a dark blue–green:

$$Fe^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow FeCO_3(s) \qquad (13.2.9)$$

Note the contrast between the reactions of $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ with washing soda solution. The $Fe^{2+}(aq)$ ions react with the carbonate ions (Equation 13.2.9); the $Fe^{3+}(aq)$ ions react with the hydroxide ions (Equation 13.2.8).

(ii) When hydrogen peroxide is added to the blue–green suspension of $FeCO_3$, it is very quickly turned into a red–brown solid. This colour suggests conversion into iron trihydroxide, $Fe(OH)_3$, which you made by the reaction between Fe^{3+} and hydroxide ions in Task 2b. The equation for the process in which hydrogen peroxide solution turns $FeCO_3$ into $Fe(OH)_3$ is:

$$2FeCO_3(s) + H_2O_2(aq) + 2H_2O(l) \longrightarrow 2Fe(OH)_3(s) + 2CO_2(g) \qquad (13.2.10)$$

where H_2O_2 is the formula of hydrogen peroxide.

(d) In this experiment, the same change takes place as in the previous experiment, that is blue–green iron carbonate, $FeCO_3$, is converted into red-brown iron trihydroxide, $Fe(OH)_3$. However, the conversion takes place more slowly because it involves the reaction of $FeCO_3$ with water and dissolved oxygen from the air, rather than with added hydrogen peroxide. The equation for the reaction is:

$$4FeCO_3(s) + O_2(g) + 6H_2O(l) \longrightarrow 4Fe(OH)_3(s) + 4CO_2(g) \qquad (13.2.11)$$

Experiment 2

Task 1

Table 13.2.4 shows the observations made by one student when she tried the electrolysis experiments.

Task 2

(a) The absence of signs of reaction at the electrodes with distilled or deionized water indicates that the conductivity of pure water is very small, and therefore the ion content is very small. Similarly, the negative result with sugar dissolved in distilled or deionized water indicates that the conductivity and ion content are not increased by the dissolution of sugar.

(b) Your observations when you tried to electrolyse tap water would depend on whether the water in your supply is hard or soft. Hard water contains small amounts of dissolved salts. These salts are present as ions, so electrolysis of water can take place, with small gas bubbles of hydrogen and oxygen appearing at the electrodes. In soft water areas, the concentration of dissolved salts, and therefore of aqueous ions, is much lower, and there may be no detectable signs of electrolysis.

(c) You should have observed a quite vigorous evolution of gas from both electrodes when you electrolysed the salt solution. This indicates that sodium chloride dissolves to give ions, which greatly increase the conductivity of the water:

$$NaCl(s) \longrightarrow Na^{+}(aq) + Cl^{-}(aq) \qquad (13.2.12)$$

Table 13.2.4 Completed version of Table 13.2.2 Record of observations of electrolysis experiments.

Task	Substance	Negative electrode	Positive electrode	Additional remarks
1a	tap water	bubbles	bubbles	more bubbles at negative electrode
1b	distilled or deionized water	nothing	nothing	presumably no conduction
1c	table salt solution	bubbles; indicator paper turns green–blue	bubbles	pungent smell like bleach, probably chlorine
1d	sugar solution	nothing	nothing	presumably no conduction
1e	washing soda solution	bubbles	bubbles	more bubbles at negative electrode; no smell this time

As the smell indicates, chlorine gas is evolved at the positive electrode, just as with electrolysis of HCl and $CuCl_2$. The comparison with HCl and $CuCl_2$ suggests that sodium metal should be discharged at the negative electrode. But what you saw during DVD-multimedia Activity 12.1 indicates that sodium metal would react with water to give hydrogen gas and a solution of sodium hydroxide.

$$2Na(s) + 2H_2O(l) \longrightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g) \quad (13.2.13)$$

So what you should observe at the negative electrode is the evolution of a gas — hydrogen — and a solution that turns the indicator paper green-blue, indicating that it is alkaline because of the presence of $OH^-(aq)$ ions.

(d) When you electrolysed washing soda solution, you should have again observed a quite vigorous evolution of gas from both electrodes. This indicates that disodium carbonate dissolves to give ions, which greatly increase the conductivity of the water. As with sodium chloride, what you should observe at the negative electrode is not deposition of sodium metal, but the evolution of hydrogen. There is no point in doing the indicator paper test in this case, because sodium carbonate solution is itself alkaline (Equation 13 2.3). The gas evolved at the positive electrode is oxygen, which is odourless. Thus in the electrolysis of a washing soda solution, you are effectively decomposing water. The dissolved sodium carbonate simply facilitates the decomposition of water by increasing its conductivity, just as adding sulfuric acid does (Section 3.5 and Figure 6.3):

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g) \quad (13.2.14)$$

You probably noticed that the gas evolved at the negative electrode was more plentiful than that at the positive electrode. This is consistent with the composition of water, and with Equation 13.2.14, because two molecules of hydrogen are produced for every molecule of oxygen. Avogadro's hypothesis (Section 8.1.1) then tells us that the volume of the hydrogen will be double that of the oxygen

Activity 14.1

(a) The similarity of radium and barium is consistent with the fact that they occur in the same group of Figure 12 7 (Group II).

(b) The elements in Group II are divalent (that is, they have a valency of two; see, for example, Table 10.2). Radium should therefore be divalent as well. Divalency implies that the formulae are RaH_2, RaF_2, $RaCl_2$, $RaBr_2$ and RaO, respectively.

(c) $RaCl_2(s) \longrightarrow Ra^{2+}(aq) + 2Cl^-(aq)$

The two chlorine atoms in $RaCl_2$ will become two $Cl^-(aq)$ ions on dissolution in water. To balance their charge, the radium atom must become an $Ra^{2+}(aq)$ ion. Notice that, as Equation 13.5 and Question 13.1 show, magnesium and calcium, which also fall in Group II, form aqueous ions with a charge of 2+.

(d) Since radium lies below, and therefore comes after, barium in the Periodic Table, it should have a higher relative atomic mass. This is the case. Marie Curie found the value for radium to be 226, whereas the barium value is 137.

In this activity you have been using your knowledge of chemical periodicity to *predict* the properties of radium. All of the predictions above are consistent with what scientists have discovered about this element, and this gives us increased confidence in the periodic law.

Activity 15.1

You may have thought of a variety of techniques that you find helpful for different types of difficulty. Below are some that students and members of the course team find useful. They include the techniques that we listed in the notes, together with some others, and as promised, we use the mole for purposes of illustration.

Try to understand the meaning of the concept by studying its definition very carefully. The advantage of this method is that it goes straight to the heart of the meaning of the concept. However, definitions are concise, and often use terms that are themselves quite difficult to understand. For example, the mole is defined in the glossary as that amount of substance whose mass is obtained by adding up the relative atomic masses of the atoms in the formula unit, and following the resulting number by the symbol for the gram. To understand this definition of the mole, you need to understand the meaning of 'relative atomic mass' and 'formula unit', and so you may need to refer to the glossary or the book to check your understanding of these terms.

Try to understand the concept by tackling questions and activities that involve it. When you first tackle a difficult concept, this is very good way to begin. In the case of the mole, you can use it to calculate empirical formulae from percentage compositions (e.g. $PtCl_4$ in Section 10.5) or to work out the amounts of reactants and products in chemical reactions, such as the combustion of methane (Section 10.3) and the reaction of lithium hydroxide in spacecraft (Section 10.4). The great advantage of tackling problems like these is that you avoid abstract general ideas, which are generally more difficult to grasp, and deal with specific cases. You follow a procedure in which the concept is used to complete an important task. Doing a set of examples involving the concept will breed confidence and familiarity, which help towards achieving a fuller understanding. However, because the questions that you are answering are rather specific, they do not necessarily equip you to use the concept in all situations.

Try to get to grips with the concept by drawing diagrams. This is a good way of getting around the abstract language in which concepts are often introduced. If you are more comfortable with diagrams than with abstract concepts, then you may find it useful to try to make sense of things in this way. Figure 10.3 does this with the mole, and Figure 8.4 presents Cannizzaro's argument in a diagram. The diagrams that you use can take a variety of forms. For example, when a concept is linked in a complicated way with other concepts, then you generally need to understand the logical relationships between them. Reaction flow diagrams (Figures 2.21, 4.3 and 6.9) attempt to do this for the substances and reactions that you met in the preceding sections. Spray diagrams of the type used in Block 2 Activity 6.3 are another good way of displaying the relationships between concepts

Represent the situation by a simplified model. When a concept is difficult to understand, it often helps if you first try to visualize a simpler situation. Once you have grasped the simpler situation, you can return to the true situation and build on the understanding you developed with the simplified model. For example, one reason why the mole is difficult to understand is that the number of formula units in a mole of any substance has the hideously large value of 6.02×10^{23}. In several places in Block 6 (Figures 5.6 and 10.2; Section 8.3) we replaced such very large numbers by very much smaller ones, and you may have found these numbers much more manageable.

Try to explain the concept in your own words. This can be helpful, because when you try to write down an explanation, you are immediately confronted with any gaps in your understanding. You can then focus on these gaps, and one way of doing this is by noting down questions that need to be answered to fill them — for example, why is the mass of a mole of hydrogen gas different from that of a mole of hydrogen ions? Or just as valuable as producing a written explanation is trying to explain a concept to another student, or to a friend or relative, particularly if they can question you about points that they don't think you have made clear.

Jumping backwards and forwards between specifics and generalities. This can be particularly helpful when you are getting to grips with the properties of chemical substances. The trends within, and the general properties of, a class of substances, tell you what a particular member of the class is like. At the same time, if you remember what some individual substances are like (e.g. hydrochloric acid), then this helps you to remember the general properties of the class to which it belongs (acids). So if you're stuck with something general like 'what is an acid?', you can jump to a specific example like hydrochloric acid and, by thinking about what it's like and what it does, get hints as to the possible general properties of the class. Conversely, if you're stuck with something specific, like the formula for the highest hydride of phosphorus, then you can jump to the generalization that tells you that, as you move across a period of typical elements, the valencies of the elements in such compounds go 1, 2, 3, 4, 3, 2, 1, 0. Then, as phosphorus is in Group V, you can deduce that its hydride is PH_3.

Try all of these things and perhaps a few more as well! Understanding difficult concepts takes time. You make sense of new ideas by relating them to what you already know, and if a concept does not fit easily into your scheme of things, a continuous assault may not be the sensible approach: you must wait and let your mind get used to the novelty. A good approach is to work over the ideas in different ways: read the block, try the questions and activities, discuss the ideas that you find difficult with a friend, ask your tutor, reread the block making notes as you go, draw diagrams, and so on. When you are doing this, your mind is constantly mulling over the ideas, even at the times when you are not consciously thinking about them. This is often what has happened when you wake up in the morning with a difficulty solved: although you may not have been aware of it at the time, your subconscious mind was ticking away, and the difficulty no longer seems to be a problem. *SGSG* 1:4.2 discusses the learning spiral, and *SGSG* 2:3.5 has some other suggestions for what to do if you get stuck. You can also find useful descriptions of what it is like to learn new ideas in science subjects in *SGSG* 6

Objectives for Block 6

The objectives state what you should understand and what you should be able to do after studying the block.

The numbers of the questions and activities that test each objective are given in italics. In the margin next to some objectives are references to *The Sciences Good Study Guide (SGSG)*, giving the chapter: section number or Maths Help (MH) number, or to DVD material, where you can find additional support.

Science content

1 Explain the meaning of, and use correctly, all the terms printed in **bold** in the text.

2 Show understanding of the pivotal roles played by water, calcium chloride, concentrated sulfuric acid, copper, copper oxide and soda lime in the investigative chemistry of the block by describing how the chemicals might be used to solve simple problems in experimental design. (*Questions 2.2, 2.4 and 2.5; Activity 6.1*)

3 Distinguish acid and alkaline solutions by their effects on other substances. (*Question 2.6)*

4 Use the idea of a chemical element to identify changes that are chemically impossible, and understand how, in simple cases, the names of compounds reflect the names of the elements that they contain. (*Questions 4.3 and 4.4*)

5 Show by calculation that you understand how the chemical formula of a binary compound, its chemical composition, and the relative atomic masses of the constituent elements are related, and calculate the percentage chemical composition of a binary compound from data on the masses of reactants and products in an appropriate chemical reaction. (*Questions 3.1, 4.1, 4.2, 6.1, 8.1, 8.4, 10.1 and 10.6; Activities 4.1, 6.1 and 10.1)*

6 Explain how the pressure exerted by a gas can be practically expressed as the height of a column of a liquid, such as mercury, that it will support. (*Questions 7.1–7.3*)

7 Use Boyle's law to correct the volume of a gas from one pressure to another, and use Charles' law to correct the volume of gas from one temperature to another. (*Question 7.4; Activity 7.2*)

8 Use a molecular model of a gas to account for gas pressure, changes of pressure and volume with temperature, and condensation. (*Activity 7.1*)

9 Use Avogadro's hypothesis to convert examples of Gay-Lussac's law into the numbers of combining molecules in the reaction, or to convert the numbers of combining molecules into an example of Gay-Lussac's law. (*Questions 8.2 and 8.3; Activities 8.1 and 10.1*)

10 Apply the principle of Cannizzaro to obtain, from the densities and chemical compositions of the gaseous compounds of an element, an estimate of the number of atoms of the element in the molecule of each compound. (*Activities 8.2 and 8.3*)

11 Calculate the relative molecular mass, or the molar mass, of a chemical substance, from the appropriate formula unit and a table of relative atomic masses, and use the molar mass to calculate the number of moles in a given mass of a substance. (*Questions 10.3–10.6 and 14.6*)

12 Calculate empirical formulae from chemical compositions using a table of relative atomic masses. Where substances are gases, use gas densities to convert empirical into molecular formulae. (*Questions 10.1 and 10.6; Activity 10.1*)

13 Deduce valencies from the empirical formulae of binary compounds and deduce empirical formulae from valencies. (*Questions 10.6 and 10.7; Activities 10.1 and 14.1*)

14 Characterize acids and basic hydroxides by their chemical formulae, and the ions that they form in aqueous solution. (*Questions 11.1 and 13.1; Activity 13.1*)

15 Identify typical elements from appropriate properties by using the appropriate section of the Periodic Table, and predict unknown properties of named elements. (*Question 12.1*; *Activities 12.1 and 14.1*)

16 Identify the atomic number of an element from its position in the Periodic Table, and relate the atomic number to the number of protons and the number of electrons in atoms. (*Questions 13.3, 14.2 and 14.4*)

17 Explain the connection between the atomic number, the mass number and the number of neutrons in the nucleus for any particular isotope; given any two of these three properties, calculate the third, and write the correct symbol for the isotope. (*Questions 14.1–14.5*)

18 Write isotope equations for examples of α-decay. (*Question 14.5*)

19 Use the Avogadro constant, N_A, to calculate the number of formula units in a given number of moles of a chemical substance. (*Question 14.6*)

Science skills

SGSG 8:2

20 Design an experiment, make observations and interpret experimental results. (*Questions 2.3 and 2.4*; *Activities 2.1, 4.1, 6.1, 6.2, 13.1 and 13.2*)

21 Use a classification scheme to group items (e.g. chemical elements) with similar properties together. (*Activity 12.1*)

22 Identify trends and patterns in properties of items (e.g. chemical elements) and make predictions on the basis of these trends. (*Activities 12.1 and 14.1*)

23 Use evidence to formulate a hypothesis, and deduce the different consequences of competing hypotheses. (*Activities 6.3, 6.4 and 8.1*)

Communicating science skills

SGSG 5:2.5; Block 6 DVD 'Balancing equations'

24 Represent chemical substances and simple chemical reactions using the correct symbols and notation, and interpret chemical formulae and equations. (*Questions 2.1, 6.1–6.4, 8.2, 8.3, 9.1, 10.2, 10.7, 11.1, 13.1 and 13.2*; *Activity 10.1*)

SGSG: 4:5

25 Present written answers to numerical questions in an appropriate way. (*Most questions and activities involving calculations*)

26 Interpret the function of apparatus shown in diagrams and, given appropriate equipment to select from, sketch diagrams of suitable apparatus for specific experiments. (*Activities 4.1 and 6.1*)

27 Write an account that criticizes someone else's science. (*Activity 6.5*)

Mathematical skills

SGSG MH1–5, 8

28 Use ratios, percentages, proportions, decimals and powers of ten to solve chemical problems. (*Questions 3.1, 4.1, 4.2, 6.1, 8.1, 10.1, 10.5, 10.6 and 14.6*; *Activities 4.1, 6.1, 8.1–8.4 and 10.1*)

SGSG MH9; Block 3 DVD 'Algebraic manipulation'

29 Rearrange and solve algebraic equations. (*Activity 7.2*)

Effective learning skills

30 Compile a glossary of chemical substances to promote familiarity with them. (*Activity 2.2*)

31 Review, and reflect upon, a lengthy argument that is presented to you in written form. (*Activities 6.3, 7.1, 10.1 and 10.2*).

32 Compile a set of techniques to resolve difficulties in understanding. (*Activity 15.1*)

Appendix 1 Relative atomic masses and atomic numbers of the elements

Element	Symbol	Atomic number	Relative atomic mass
actinium	Ac	89	227
aluminium	Al	13	27.0
americium	Am	95	243
antimony	Sb	51	122
argon	Ar	18	39.9
arsenic	As	33	74.9
astatine	At	85	210
barium	Ba	56	137
berkelium	Bk	97	247
beryllium	Be	4	9.01
bismuth	Bi	83	209
bohrium	Bh	107	264
boron	B	5	10.8
bromine	Br	35	79.9
cadmium	Cd	48	112
caesium	Cs	55	133
calcium	Ca	20	40.1
californium	Cf	98	251
carbon	C	6	12.0
cerium	Ce	58	140
chlorine	Cl	17	35.5
chromium	Cr	24	52.0
cobalt	Co	27	58.9
copper	Cu	29	63.5
curium	Cm	96	247
dubnium	Db	105	262
dysprosium	Dy	66	163
einsteinium	Es	99	252
erbium	Er	68	167
europium	Eu	63	152
fermium	Fm	100	257
fluorine	F	9	19.0
francium	Fr	87	223
gadolinium	Gd	64	157
gallium	Ga	31	69.7
germanium	Ge	32	72.6
gold	Au	79	197
hafnium	Hf	72	178
hassium	Hs	108	269
helium	He	2	4.00
holmium	Ho	67	165
hydrogen	H	1	1.01
indium	In	49	115
iodine	I	53	127
iridium	Ir	77	192
iron	Fe	26	55.8
krypton	Kr	36	83.8
lanthanum	La	57	139
lawrencium	Lr	103	262
lead	Pb	82	207
lithium	Li	3	6.94
lutetium	Lu	71	175
magnesium	Mg	12	24.3

Element	Symbol	Atomic number	Relative atomic mass
manganese	Mn	25	54.9
meitnerium	Mt	109	268
mendelevium	Md	101	258
mercury	Hg	80	201
molybdenum	Mo	42	95.9
neodymium	Nd	60	144
neon	Ne	10	20.2
neptunium	Np	93	237
nickel	Ni	28	58.7
niobium	Nb	41	92.9
nitrogen	N	7	14.0
nobelium	No	102	259
osmium	Os	76	190
oxygen	O	8	16.0
palladium	Pd	46	106
phosphorus	P	15	31.0
platinum	Pt	78	195
plutonium	Pu	94	244
polonium	Po	84	210
potassium	K	19	39.1
praseodymium	Pr	59	141
promethium	Pm	61	145
protactinium	Pa	91	231
radium	Ra	88	226
radon	Rn	86	222
rhenium	Re	75	186
rhodium	Rh	45	103
rubidium	Rb	37	85.5
ruthenium	Ru	44	101
rutherfordium	Rf	104	261
samarium	Sm	62	150
scandium	Sc	21	45.0
seaborgium	Sg	106	266
selenium	Se	34	79.0
silicon	Si	14	28.1
silver	Ag	47	108
sodium	Na	11	23.0
strontium	Sr	38	87.6
sulfur	S	16	32.1
tantalum	Ta	73	181
technetium	Tc	43	98.0
tellurium	Te	52	128
terbium	Tb	65	159
thallium	Tl	81	204
thorium	Th	90	232
thulium	Tm	69	169
tin	Sn	50	119
titanium	Ti	22	47.9
tungsten	W	74	184
uranium	U	92	238
vanadium	V	23	50.9
xenon	Xe	54	131
ytterbium	Yb	70	173
yttrium	Y	39	88.9
zinc	Zn	30	65.4
zirconium	Zr	40	91.2